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SOME RECENT PUMPING ENGINE TESTS.

By Frank A. Whitten.*

An interesting addition to the water supply of the city of Chicago has recently been completed. New pumping machinery, in conjunction with the new intake and tunnel system, has increased the daily pumping capacity of the Chicago waterworks by 120,000,000 gallons. As there are a number of unusual features in connection with the installation, the following brief description and report of tests are given:

The source of supply is, of course, Lake Michigan. The water is taken from a point a little over 2½ miles out from the shore, and at a depth of about 24 ft. below the surface, the total depth at this point being 34 ft. A permanent intake crib (known as the Carter H. Harrison Crib†) was built up from the bottom of the lake, and in its interior a shaft was sunk to connect with the tunnel extending under the bottom of the lake to the shore.

The tunnel from the crib to the shore is 10 ft. in diameter inside. It has a circular cross-section and is lined throughout with three rings of brick laid in Portland cement. The digging of this tunnel was prosecuted from both ends and from a temporary crib and shaft near the middle of its length. The total length of this tunnel is 14,033 ft., and its total cost, including the crib, was approximately $574,000.

From a shaft on the shore, a similar 10-ft. tunnel, nearly 100 ft. below the street level, extends under the city for a distance of 8,660 ft. to the intersection of Green St. and Grand Ave. At this point it branches into two 8-ft. tunnels. One of the branches leads to the shaft in the Central Park Ave. Pumping Station, a distance of 19,856 ft., and the other to the shaft of the Springfield Ave. Pumping Station, a distance of 22,184 ft. All the land tunnels are lined with brick, as are the lake tunnels.

Practically the two pumping stations are duplicates in size, arrangement, machinery and other equipment. Therefore, a description of one will suffice for both.

*Erecting Engineer, Henry R. Worthington, 114 Liberty St., New York City.

†Described and illustrated in Engineering News of Aug. 19, 1899.

Fig. 1 shows an exterior view of the Central Park Ave. Station, and Figs. 2 and 3 show the arrangement of boilers, engines, etc., inside of the station. The arrangement is unusual in that there is no floor other than that of the bottom of the pump pit and a narrow gallery all around the engine room a little above the street level and about 45 ft. above the basement floor. This does away with the necessity of using artificial light in the basement in the daytime, and results in a very clean engine room, as there are no dark corners to catch rubbish and dirt.

Sunk in the center of the engine room floor is a vertical shaft connecting with the supply tunnel. Rising above the floor is an extension of this shaft built of boiler plate, and lined with brick. In this extension the water rises and would stand, of course, at the same level as in the lake were no engines taking water from the tunnel. When the stations are in operation this water level falls several feet, the amount of fall depending on the number of engines running.

There are in each station three engines. Each engine has its own suction pipe, 42 ins. in diameter, extending through the wall of the wet well near the basement floor line, and turning down into the shaft. From the water end of each engine a 36-in. discharge pipe runs out through the walls of the pit and connects with the general system of mains supplying the whole city. It is interesting to note that all the supply pipes of the city are inter-connected and supplied by 32 engines, there being no stand-pipes, reservoirs, or other means of regulating the pressure, except the amount of consumption and supply.

In the boiler room of each station there are six boilers rated at 225 HP each. They are of the Scotch marine type, each having two 40 in. corrugated "Morrison" furnaces, and 140 2½ in. tubes. The shells are 10 ft. in diameter, and 12 ft. long. They were built by John Mohr & Sons, Chicago. For each boiler there is a Hawley down-draft furnace. The water-grates of these furnaces, being connected to the boilers at two points, one just below the water line, and the other near the bottom, insure a good circulation in the boilers. Due to the use of these furnaces, there is an almost total absence of smoke, even when burning very poor bituminous coal.

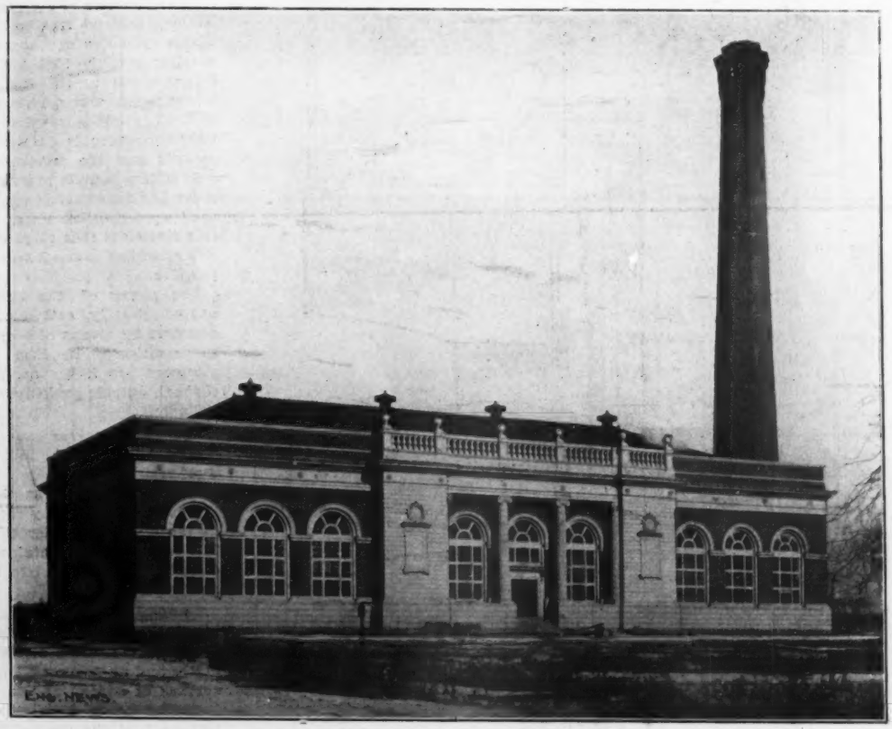


FIG. 1. CENTRAL PARK AVE. PUMPING STATION, CHICAGO WATER-WORKS.

Coal is dumped from cars on the railroad siding into the crusher hopper. The crusher feeds the coal into an endless chain bucket conveyor, which carries it up, and dumps it into any desired portion of the bunker above the boiler room. A quite unusual feature of the conveyor is that there are 90° twists in the chain of buckets, different portions of the chain thus running at right angles to each other, and one conveyor doing the work usually calling for two. Fig. 2 shows this arrangement quite plainly. The crusher, conveyor, driving engine, and so forth, were built by the C. W. Hunt Co., and installed by the McDonald Engineering Co., of Chicago.

The feed water for the boilers is taken from the delivery mains, and passes first through the closed heaters in the main exhaust pipes between the engines and the condensers. Then it passes to the feed pumps through an auxiliary heater in the boiler room. This heater is a standard Worthington closed heater, and into it is led the exhaust of the feed pumps and other auxiliary machinery. The two Worthington feed pumps send the water into "Buffalo" purifiers, from which it flows by gravity into the boilers.

The steam on leaving the boilers passes into a header extending along over all the boilers. In the combustion chamber in the rear of each boiler is a Foster superheater. Each superheater has a connection to the header above mentioned. An

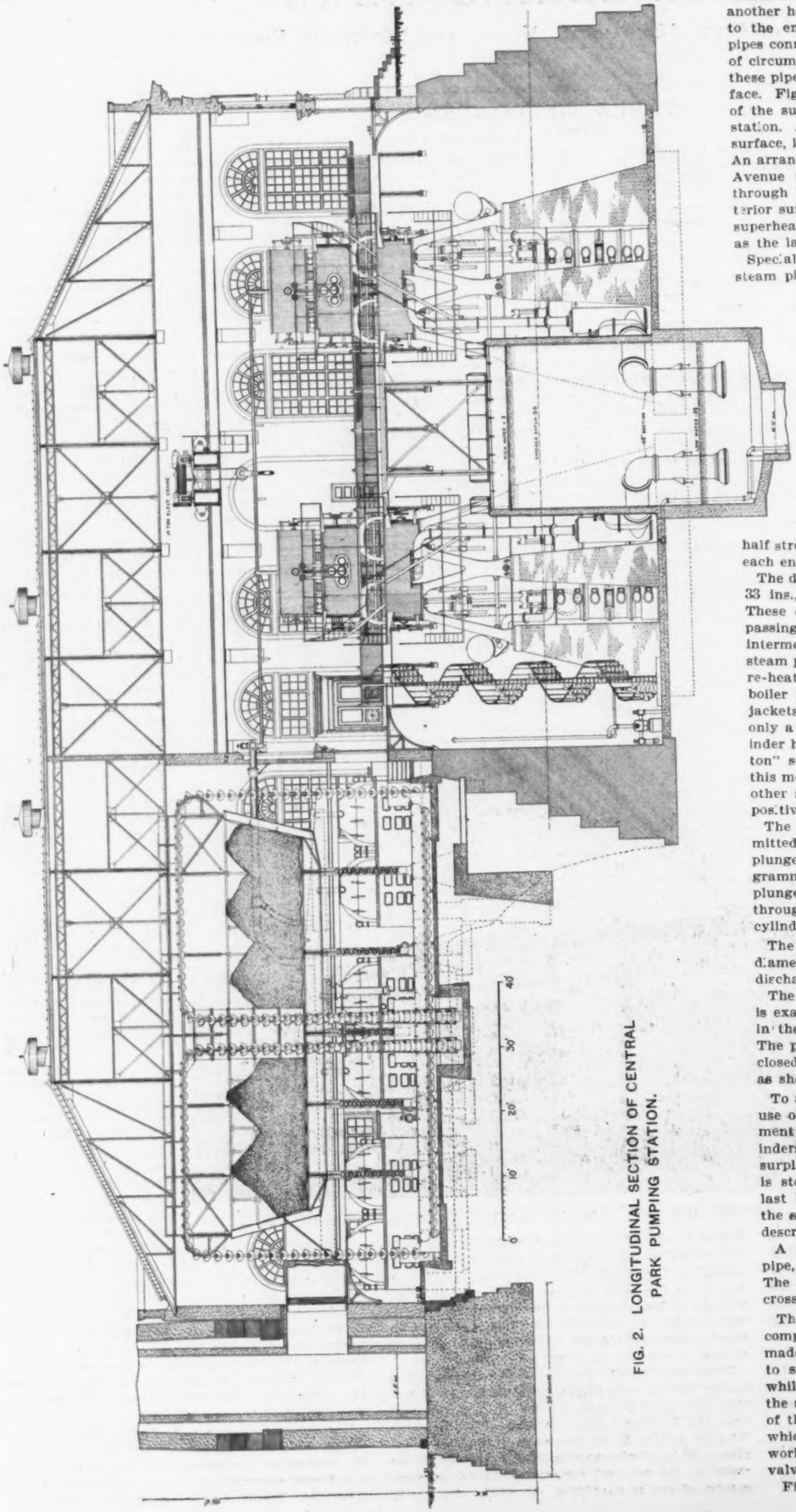


FIG. 2. LONGITUDINAL SECTION OF CENTRAL PARK PUMPING STATION.

outlet connection leads from each superheater into another header, from which connections are made to the engines. These superheaters consist of pipes connected by return bends. A large number of circumferential ribs are cast on the exterior of these pipes, and serve to increase the heating surface. Fig. 4 shows the arrangement and location of the superheaters in the Central Park Avenue station. A similar arrangement, but with less surface, is used at the Springfield Avenue station. An arrangement inside the pipes in the Springfield Avenue superheaters brings the steam passing through into more intimate contact with the interior surface of the superheaters, thus making a superheater with less surface do the same work as the larger ones at Central Park Avenue.

Special care had to be taken in laying out the steam piping in order to allow for the great expansion due to the use of superheated steam. The superheaters were designed and built by the Power Specialty Co., of New York.

The engines, which were built by Henry R. Worthington, are of the standard Worthington triple expansion "high duty" type. Each has a rated capacity of 20,000,000 gallons per 24 hours against 150 ft. head.

Each engine practically consists of two vertical tandem triple-expansion engines, independent of each other, except that one controls the steam valves of the other, one side thus always keeping just one half stroke ahead of the other. The total height of each engine is about 60 ft.

The diameters of the steam cylinders are 21 ins., 33 ins., and 60 ins., and their stroke is 50 ins. These cylinders are steam-jacketed all over. In passing from the high to the intermediate, and the intermediate to the low pressure cylinders, the steam passes through receivers in which are brass re-heating pipes supplied with live steam. Full boiler pressure is carried on the h. p. and i. p. jackets and the receivers. On the l. p. jackets only a few pounds pressure is carried. Each cylinder has four valves, operated by the "Worthington" semi-rotative valve motion. The feature of this motion is that there are no trips, dashpots, or other similar arrangements, all movements being positive.

The power of the steam cylinders is transmitted directly, and in a straight line, to the plungers by means of a system of rods shown diagrammatically in Fig. 5. The double-acting plungers are 34½ ins. in diameter, and work through outside packed stuffing boxes in the water cylinders.

The pump valves are of rubber, and of small diameter, there being 97 in each suction, and each discharge deck.

The weight of all the pistons, plungers and rods is exactly balanced by means of a water pressure in the cylinders under the "balancing plungers." The pressure is maintained by air pumped into a closed tank connected to the balancing cylinders, as shown in Fig. 5.

To admit of an early cut-off and the economical use of steam, the Worthington high duty attachment is used. This consists of compensating cylinders and an accumulator, by means of which the surplus of energy at the beginning of the stroke is stored up to be liberated and utilized in the last half of the stroke during the expansion of the steam. This arrangement has been too often described to need any further comment here.

A surface condenser is placed in the suction pipe, and all the water pumped passes through it. The air pump is driven from the main engine cross-head.

The accompanying table gives the results, as compiled from the official reports, of the tests made of these engines and boilers. It is only fair to state that the test of Engine 1201 was run while one i. p. valve spindle was twisted so that the steam valve opened about 6 ins. from the end of the exhaust stroke. This was caused by a pin which had been left somewhere in the engine working into the port, and getting caught by the valve.

Fig. 6 is a reproduction of indicator cards from

the high, intermediate and low pressure steam cylinders.

Examinations of various cylinders and steam valves of the engines have been frequently made since the use of superheated steam was begun. Absolutely no bad effects have been found, and all the cylinders and valves are in perfect condition after the use of superheated steam for an average time of nearly two years. No precautions were taken to avoid trouble. The same medium grade of cylinder oil is in use as was used for saturated steam, but it has been found that less of it is necessary since the superheated steam carries no moisture.

The writer recalls accompanying to one of these stations a party of foreign engineers. When approaching the station, one of them remarked that the plant seemed to be shut down. His reason for so thinking was the utter absence of visible smoke from the stack. On stepping into the engine room another of them exclaimed that the engines were not running. This was a most natural mistake, as the operation of all three engines at once was almost absolutely noiseless, the only moving parts visible being the valve motion and compensating cylinders, which are not very noticeable at first glance.

A large number of engineers, both from this country and abroad, have stated that they have never seen the equal of these stations for quietness and ease of operation. It is interesting to note that some of these engines have run as quietly, for days at a time, at a rate to exceed 22,000,000 gallons per twenty-four hours. A study of the tabulated results of the tests will show the very high economy of the plants. Such results have never before been obtained with this type of engine. These tests were conducted by a board composed of the Robert W. Hunt Co., representing the City; Mr. F. J. Oakes, representing Henry R. Worthington, and Mr. Thomas T. Johnston, as the third and disinterested engineer.

All the usual precautions for securing accuracy were observed in making the tests. All the data were obtained and recorded by a corps of observers from the Robert W. Hunt Co., and from the Engineering Bureau of the city. Condensed steam from the condenser and from the jackets was carefully weighed, as was the coal burned, and the water fed into the boilers. All blow-offs and cross connections were broken and blank flanged. The pump valves were examined, and found to be tight. All gages and other instruments were carefully calibrated before and after each test. The length of stroke of the engines was determined in the following manner: Attached to the cross-heads were pointers which traveled over scales fixed to the frames of the engines. These scales were graduated, from the ends toward the middle, in tenths of an inch. During tests, observers read the shortages from the ends of the scales every 15 minutes. These readings were all averaged. The average thus found was deducted from the distance between the ends of the scales, the remainder being the average length of stroke. The steadiness of the stroke of the engines, con-

TABLE OF RESULTS OF DUTY TRIAL OF BOILERS AND PUMPING ENGINES, CENTRAL PARK PUMPING STATION, CHICAGO.

	E 1,200	E 1,202	E 1,201	E 1,205	E 1,203	E 1,204
Number of engine						
Date	11-(9-10)-'03	11-(12-13)-'03	11-(16-17)-'03	8-(27-28)-'02	9-(3-4)-'02	9-(8-9)-'02
Duration of trial (hrs.)	24	24	24	24	24	24
Steam pressure at throttle (lbs.)	146.8	142.27	146.88	144.45	147.3	144.8
" " on HP. and IP. jackets and reheater coils (lbs.)	146.8	142.27	146.88	144.45	147.3	144.8
" " on LP. jackets (lbs.)	8.98	6.34	9.46	10.13	10.1	9.8
Vacuum in exhaust pipe close to LP. cylinders (ins. of mercury)	27.05	26.73	26.87	26.98	26.7	26.8
Barometer (lbs.)	14.356	14.26	14.385	14.45	14.45	14.35
Balancing pressure (lbs.)	73.2	75.4	73.3	78.97	75.8	80.5
Delivery pressure (gage reading, lbs.)	52.574	52.03	52.43	52.23	52.42	52.34
" " " (ft.)	121.306	120.05	121.07	120.65	121.08	120.9
Height of delivery gage above water in well (ft.)	31.95	31.95	31.96	32.24	32.72	32.78
Total head on pumps (ft.)	153.256	152.00	152.93	152.89	153.80	153.68
Temperature of water pumped (F°)	40	40	40	72	73	73
" " feed water after passing heater in exhaust pipe (F°)	106.2	99.6	56.02	102.18	104.7	100.9
" " steam at the throttle (F°)	451.1	432.7	424.25	516.91	491.0	505.7
Number of degrees superheat in steam at the throttle (F°)	87.2	71.2	63.4	154.0	126.7	142.8
Total cond. steam from air-pump or used in engine cylinders (lbs.)	151,260	153,849	156,174	143,734	159,216	152,773
Jacket water or steam used in cylinder jackets and reheaters (lbs.)	17,431	16,678	12,760	16,400	17,974	15,295
Total steam used by engine (lbs.)	168,691	170,527	168,934	160,134	177,190	168,067
Percentage of jacket water	10.33	9.78	7.55	10.24	10.1	9.09
Total dry coal burned to evaporate steam used by engine (lbs.)	18,296	17,799	19,286	18,534	21,322.5	20,072
Total revolutions of engine per 24 hrs	26,821	26,515	26,094	27,814	27,335	27,038
Average revolutions per min.	18.63	18.41	18.2	19.33	18.97	18.76
" piston speed per min. (ft.)	154.55	153.04	151.06	159.74	157.22	155.33
" length of stroke (ins.)	49.778	49.88	49.8	49.587	49.73	49.68
" plunger displacement per revolution (gals.)	799.165	800.8	799.52	794,072	799.36	797.72
" " " " " (cu. ft.)	106.83	107.48	106.88	106.148	106.84	106.64
" " " " " (lbs.)	6,668.5	6,681.9	6,671.6	6,613.02	6,656.1	6,643.67
" " " per 24 hours (gals.)	21,434,420	21,233,212	20,862,674	22,086,318	21,850,505	21,568,753
" " " " " (cu. ft.)	2,865,362	2,838,377	2,788,979	2,952,400	2,920,471	2,883,332
" " " " " (lbs.)	178,854,319	177,171,533	174,088,052	183,934,538	181,855,308	179,631,603
Allowance for slip and leakage (gals.)	107,172	106,166	104,313	110,431	109,253	150,981
" " " (cu. ft.)	14,326	14,191	13,945	14,762	14,602	20,183
" " " (lbs.)	894,271	885,857	870,440	919,672	909,276	1,257,421
Net water pumped per 24 hours (gals.)	21,327,248	21,127,046	20,758,361	21,975,885	21,741,253	21,417,772
" " " " (cu. ft.)	2,851,036	2,824,186	2,775,034	2,937,638	2,905,869	2,863,140
" " " " (lbs.)	177,960,048	176,285,676	172,217,612	183,014,865	180,946,091	178,374,182
Net work delivered per 24 hours (ft.-lbs.)	27,273,445,116	26,795,422,752	26,455,525,880	27,981,142,800	27,829,508,841	27,412,544,335
Net delivered horse power	573.93	563.87	556.72	588.82	585.60	576.8
Indicated horse power	645.98	601.84	598.64	660.90	674.45	661.0
Efficiency (%)	88.8	93.6	92.6	89.15	86.8	87.3
Steam used per indicated horse power per hour (lbs.)	10.00	10.64	10.88	10.01	10.90	10.53
" " net delivered horse power per hour (lbs.)	12.25	11.37	12.63	11.32	12.60	12.10
Dry coal used per indicated horse power per hour (lbs.)	1.18	1.23	1.34	1.42	1.52	1.307
" " per net delivered horse power per hour (lbs.)	1.32	1.31	1.45	1.58	1.74	1.49
Combustible used per indicated horse power per hour (lbs.)	1.05	1.12	1.19	1.07	1.19	1.14
" " per net delivered horse power per hour (lbs.)	1.18	1.19	1.28	1.20	1.37	1.33
Duty per 1,000 lbs. of steam used (ft.-lbs.)	161,676,942	157,133 021	156,602,731	174,735,801	157,080,267	163,104,857
Duty per 100 lbs. of coal used (ft.-lbs.)	149,067,802	150,592 270	137,502,733	150,971,958	130,517,109	132,607,122

TEST OF BOILERS.

	E 1,200	E 1,202	E 1,201	E 1,201	E 1,205	E 1,203	E 1,204
Number of engine test corresponding							
Date of test	11-(9-10)-'03	11-(12-13)-'03	11-(16-17)-'03	11-(16-17)-'03	8-(27-28)-'02	9-(3-4-'02	9-(8-9)-'02
Kind of fuel	Maryland Smokeless.	Pocahontas.	Jupiter lump.	Maryland Smokeless.	Maryland Smokeless.	Maryland Smokeless.	Maryland Smokeless.
Grate surface (upper grate only) (sq. ft.)	35	35	35	35	35	35	35
Water heating surface (sq. ft.)	1,402	1,402	1,402	1,402	1,402	1,402	1,402
Superheating surface (external) (sq. ft.)	268	268	268	268	375	375	375
" " (internal) (sq. ft.)	130	130	130	130	180	180	180
Duration of test (hours)	24	24	24	24	24	24	24
Weight of coal fired (lbs.)	24,522	21,957	5,100	21,600	22,779	24,797	25,419
Percentage of moisture in coal (from analysis)	0.52	0.54	1.0	0.52	0.88	0.84	0.91
Total weight of dry coal consumed (lbs.)	24,395	21,839	5,049	21,488	22,519	24,589	25,188
Total ash and refuse (lbs.)	2,693	1,931	1,195	2,321	1,861	2,313	2,720
Percentage of ash and refuse in dry coal	10.98	8.82	23.43	10.74	8.17	9.3	10.7
Total weight of water fed to boiler (lbs.)	224,978	200,255	35,740	188,710	195.153	204,897	204,797
Factor of evaporation (including superheat)	1.131	1.145	1.2703	1.2703	1.166	1.157	1.1702
Equivalent water evaporated into superheated steam from and at 212°	254,450	239,566	45,400	230,718	227,548	237,066	239,653
HOURLY QUANTITIES.							
Dry coal consumed per hour (lbs.)	1,016.4	910.0	1,263	1,074.4	940.7	1,024.5	1,049
" " " per sq. ft. grate surface (upper grate) (lbs.)	29.04	26.0	36.05	30.69	26.87	29.27	29.97
Equivalent evaporation per hour from and at 212° (lbs.)	10,602	9,981.9	11,350	11,985.9	9,481.7	9,877.7	9,985.5
Equiv. evaporation per hr. from and at 212° per sq. ft. heating surface (lbs.)	7.562	7.11	8.09	8.55	6.7	7.04	7.11
AVERAGE PRESSURES, ETC.							
Steam pressure by gauge (lbs.)	158.9	150.6	151.23	151.23	154.22	157.2	156.5
Temperature of feed water entering purifier (F°)	189.1	185.0	162.40	162.40	177.26	179.5	175.4
Temperature of escaping gases from boiler (F°)	.....	.....	542	542	459	464.7	450.0
Force of draft between boiler and damper (ins. of water)	.706	.693	.78	.78	.....	.....	.....
Number of degrees of superheating	113.7	108.57	98.3	98.3	162.0	149.9	165.6
HORSE POWER.							
HP. developed	307.3	289.3	328.9	347.4	275.0	286.3	290.0
Builder's rated HP.	225.0	225.0	225.0	225.0	225.0	225.0	225.0
Percentage of builder's rated HP. developed	136.6	128.6	146.2	154.4	122.2	127.2	128.9
ECONOMIC RESULTS.							
Water evaporated under actual conditions per lb. of coal fired (lbs.)	9.174	9.530	7.008	8.736	8.567	8.263	8.046
Equivalent evaporation from and at 212° per lb. of coal as fired (lbs.)	10.376	10 910	8,902	11.098	10.077	9.560	9.428
" " " " " " of dry coal (lbs.)	10.428	10,96	9.000	11.010	10.110	9.980	9.510
" " " " " " of combustible (lbs.)	11.717	12.04	11.780	12.510	10.97	10.600	10.060
EFFICIENCIES.							
Calorific value of dry coal per lb. (B. T. U.)	14,191	14,260	.....	14.191	14,213	14.368	13.531
" " of combustible per lb. (B. T. U.)	15,715	15,732	.....	15,991	15,634	15,426	14,125
Efficiency of boiler (based on combustible) (per cent.)	72.00	73.90	.....	75.54	67.76	66.35	68.18
" " including grate (based on dry coal)	70.96	74.22	.....	79.00	68.09	64.52	67.84
Cost of coal per ton of 2,000 lbs., $	4.00	3.90	2.57	4.00	2.89	2.89	2.99
Cost of coal required to evaporate 1,000 lbs. of water from and at 212° (cts.)	19.3	17.4	12.6	18	14.4	15.1	15.4

sidering the fact that they are operated together on a direct pressure system, is remarkable. The stroke of these engines has been watched by a good many engineers, all of whom have expressed surprise at its constancy. During three of these tests all observations were made every thirty minutes, and during the last three tests the readings were taken every fifteen minutes.

The whole system was planned and the work

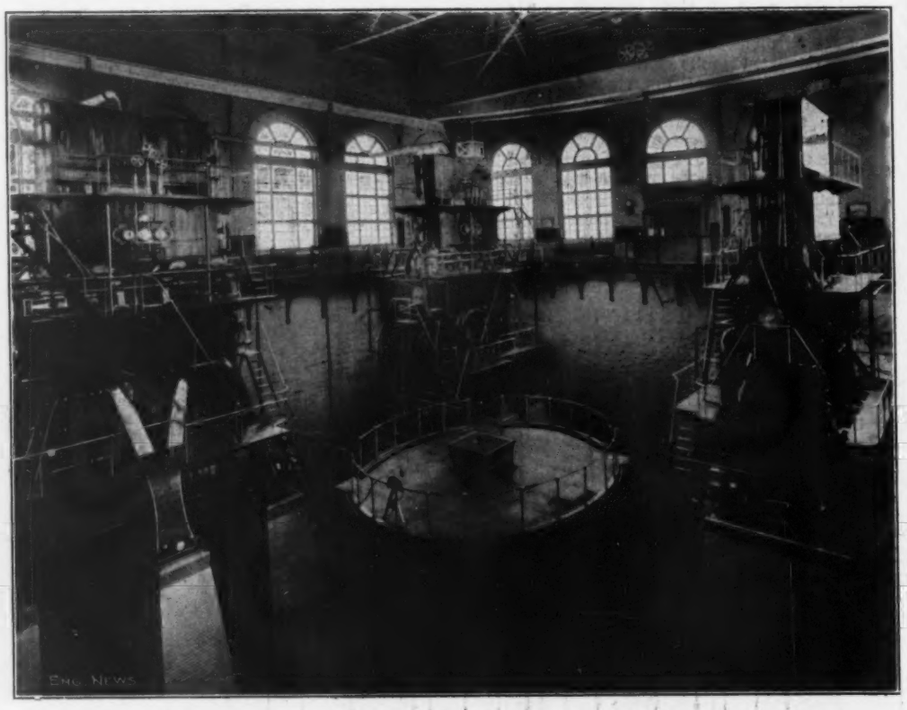


FIG. 3. INTERIOR VIEW OF CENTRAL PARK PUMPING STATION.

carried on under the supervision of the Bureau of Engineering of the City of Chicago—Mr. John Ericson, City Engineer, and Mr. J. H. Spengler, Asst. City Engineer. The inspecting was done by the Robert W. Hunt Co. The total cost of the whole system was approximately $4,000,000.

EXPLOSIONS PRODUCED BY FERRO-SILICON.*

By A. Dupre, Ph. D., F. R. S.,† and Capt. M. B. Lloyd, R. A.‡

I. CIRCUMSTANCES OF THE EXPLOSIONS.

Having in view the extent to which ferro-silicon is in use, it seems that it is a matter of some importance that the Institute should be in possession of the particulars of several explosions which occurred in connection with a consignment of this material from the Cunard Company's steamship "Veria" at the Alexandra Dock, Liverpool.

The vessel, which had brought a cargo from Triest, was discharged Dec. 17, 1903, and owing, it is said, to a fire having occurred on the vessel, the ferro-silicon was detained on the quay until Jan. 12, when Messrs. Beck & Co., of 61 South John St., Liverpool, removed the forty-eight drums, in which the ferro-silicon was contained, to a warehouse in Dacre St., Bootle.

They were seen there on a lorry by Inspector Jones of the Explosives Department of the Liverpool Police, whose attention was drawn to them by the strong smell of acetylene gas; this smell, as will be shown, was doubtless due to phosphoretted hydrogen, the unpleasant odor of ordinary acetylene being due to the presence of traces of this gas. Shortly after, whilst a drum was being rolled from the truck on to the concrete floor of the warehouse, a violent explosion occurred followed by flame. The drums were then removed to an open yard, and during this removal a second drum exploded.

It was then considered advisable to place the ferro-silicon in wooden barrels; this was done, and holes were said to have been bored in the end of the casks to prevent the accumulation of any inflammable gas. These measures were however of no avail, for on Jan. 21 a porter employed by the Liverpool Warehousing Company was engaged in weighing some of the barrels and was in the act of removing one from the machine when it exploded. The barrel was blown to pieces, and the man was thrown seven to eight yards away, and, being severely bruised, was removed to hospital.

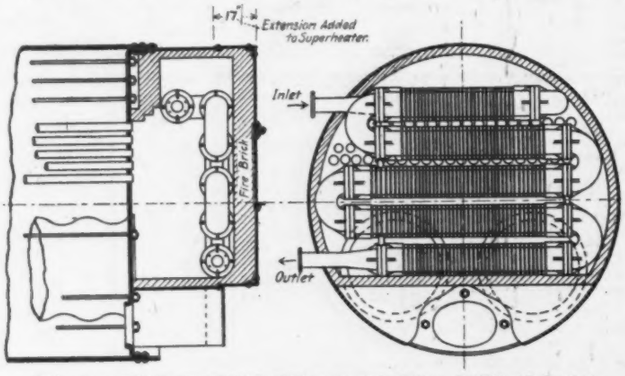


FIG. 4. STEAM SUPERHEATERS IN CENTRAL PARK STATION.

II. CAUSE OF THE EXPLOSIONS.

A sample of the ferro-silicon was obtained by us through the head constable of Liverpool, and was submitted to an examination with a view to ascertaining the cause of the explosions. This examination showed that:

The substance when moistened evolved, even in the cold, an inflammable gas which consisted at any rate in far greater part of phosphoretted hydrogen.

Neither acetylene nor siliciuretted hydrogen could be detected, and at most minute traces only of these gases could have been present. (Ferro-silicon yields no siliciuretted hydrogen with water, but only when acted on by strong acids.)

For the determination of the cause of this explosion the exact composition of the gas is not a matter of essential importance, the main point is that the gas is inflammable and forms an explosive mixture with air. Experiment has shown that 4 kilogrammes of the powdered ferro-silicon will make 64 liters of air explosive. Its temperature of ignition is low, considerably below a red heat; indeed, pure phosphoretted hydrogen (PH_3), which is not spontaneously inflammable, is stated to ignite at a temperature of 200° C.

Such a temperature may, we think, very well be produced by the friction of the irregularly shaped hard lumps of ferro-silicon, either against each other or against the sides of the drum, when subjected to rough treatment.

The experiments were made by one of us with small quantities of finely powdered material; but this brings in plainly the element of time, and moreover in the case of a hard and brittle material like this, a quantity of more or less fine powder is sure to be produced during transport.

The gas evolved by treatment with water ignites when it comes into contact with strong nitric acid. In none of our experiments, however, did the phosphoretted hydrogen evolved inflame spontaneously; it is, however, well known that when produced under certain conditions it is liable to spontaneous ignition.

From these considerations we have therefore formed the opinion that the explosion was most probably caused by water having got into the interior of the drums; the gas evolved formed, with the air in the drums, an easily ignited explosive mixture, which was fired by the heat produced by the friction of the hard lumps against each other when the drums were moved about, or possibly by the spontaneous ignition of some phosphoretted hydrogen contained in a pocket in the material, and liberated suddenly by the breaking of a lump on the drum being moved.

Mr. G. Watson Gray, who read a note on this subject at a meeting of the Faraday Society on Feb. 2, also attributes the explosion to the presence of phosphorus, but he found acetylene and arseniuretted hydrogen among the gases generated in the casks, though he did not apparently find any acetylene in the gases generated by the sample which he boiled with water in his laboratory.

Mr. Watson Gray, whose experience in metallurgical analysis is well known to the members of this institute, has kindly furnished us with the results of his analysis of a piece of the metal.

These are as follows:

	Per cent.
Silicon	59.40
Iron	36.85
Manganese	0.08
Aluminum	2.73
Calcium	0.14
Magnesium	0.17
Carbon	0.218
Sulphur	trace
Phosphorus	0.056

The results of this analysis, when compared with those given by him in his paper on the "Presence of Calcium in High Grade Ferro-Silicon,"* tend to show that the sample was of more than average purity, the percentage of foreign substances being under 4%, whereas in none of

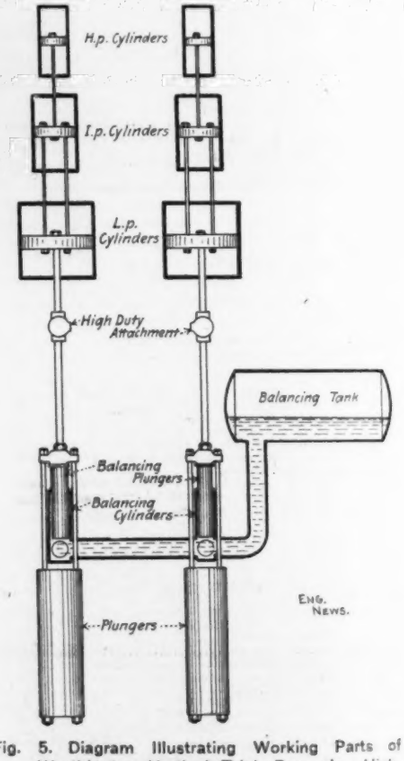


Fig. 5. Diagram Illustrating Working Parts of Worthington Vertical Triple-Expansion High-Duty Engine.

*A paper read before the Iron and Steel Institute, May, 1904.

†Chemical Adviser to the Explosives Department, Home Office.

‡H. M. Inspector of Explosives.

*Journal of the Iron and Steel Institute, 1901, No. II. p. 144.

those referred to is that percentage much below 7%, and that only with a low proportion of silicon; but it should be noted that although the percentage of calcium is lower, that of phosphorus is higher in this case than they are respectively in any of these reported in Mr. Watson Gray's paper.

III. PRECAUTIONS TO AVOID RISK IN FUTURE.

It would appear, therefore, that these explosions are probably due, not to the ferro-silicon itself, but to the presence of impurities, and more particularly to the phosphorus compounds contained in it. The best method of avoiding such risks in future would be to use such materials only as are free from phosphorus, or if this be found

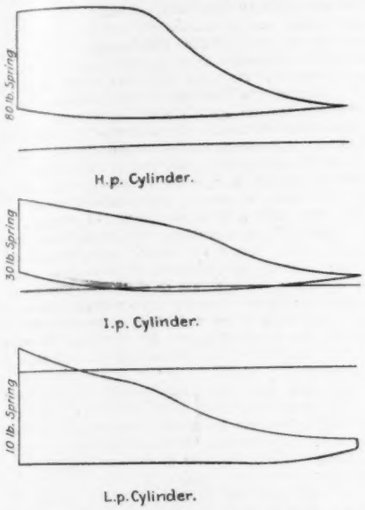


Fig. 6. Sample Indicator Cards from Central Park High-Duty Pumping Engine.

impossible, to fill up the drums with paraffin oil of high flashing point, or lastly by submerging the finely divided material in water until all action has ceased, and drying the material before packing, as it is improbable that on a large scale every particle of phosphide of calcium or other gas-generating substance would be removed by this latter treatment. The drums used should, as an additional precaution, be perfectly water-tight, and of such strength and construction as not to be liable to become insecure under the ordinary conditions of transport.

An alternative precautionary measure would be only to send solid ingots well tarred and packed in drums as above described, but we have no means of knowing whether such a measure would be practicable.

Drums suitable for packing the broken ferro-silicon are already in common use for the purpose of packing carbide of calcium, though we should be sorry to be taken to mean that any carbide drum will fulfill the requirements, many of those in use, particularly some of foreign manufacture, being considerably below a desirable standard.

In conclusion we would point out that although the accident now under consideration was not attended with any very grave results, the possibility of an explosion on a far larger scale must not be lost sight of. It is important, therefore that all those who have to store or handle this substance should be fully alive to the possible dangers attaching to it, and by keeping it in a dry and thoroughly well-ventilated place prevent the accumulation of inflammable gas as far as possible. We would suggest also that all products of an electric smelting-furnace should be treated with similar precautions until such time as enough is known about them to be certain that these risks do not attach to them.

We cannot conclude without expressing our appreciation of the kindness of Mr. Watson Gray in furnishing us with the results obtained by him and allowing us to use them for the purposes of this paper.

CONCRETE STEEL CRIBWORK WHARF CONSTRUCTION AT DEPOT HARBOR, ONTARIO.

A cribwork of reinforced concrete beams, jointed and laid up in all respects like timber cribwork, is now being employed in the construction of a wharf 400 ft. long and 150 ft. wide at Depot Harbor, Ontario. The novelty of this construction and the fact that it has been specified for constructing a 2,400-ft. breakwater at Port Colborne, Ontario, make its description of interest to engineers, and we accordingly present full drawings of the Depot Harbor wharf now under construction. As a preface to the description, it should be noted that this system of cribwork construction was worked out and has been patented by Mr. T. W. Fraser, one of the engineers of the Canadian Department of Public Works, under whose control both of the structures mentioned above will come during and after construction.

The wharf at Depot Harbor is 150 ft. wide and extends straight out from the shore a distance of 400 ft. On the three water sides the structure consists of the cribwork wall under construction, and the intermediate space is earth fill. The cribwork is the only feature that calls for consideration, and this is shown in cross-section and in plan and front elevation by the three drawings of the accompanying engraving. In explanation it should be stated that the concrete cribbing was substituted for one of wood and that in making the alteration the wooden structure originally planned was not changed below low water level. The specifications describe the new structure clearly, and we, therefore, quote them as follows:

The superstructure shall be built 7 ft. high above low water level, and have an average width of 10¼ ft. It shall be composed of concrete members framed and well secured together and to the substructure, and the whole as shown on plans. The outer face of the work shall be closefaced.

FACE MEMBERS.—The concrete members composing the outer face of the superstructure shall be molded in 12 × 12 ins. dimensions and in lengths of not less than 20 ft., except those between the heads of crossties, which will be in lengths of 9 ft. 1½ ins. over all. The corner joints shall be made as shown on the plan, the corners being protected by iron plates anchored into the members. In every member holes 2½ ins. in diameter shall be left at the points of contact, at distances shown on the plan, for the insertion of cement grouting and of rods 1 in. in diameter, 7 ft. long. These rods shall be pressed down into the holes immediately after they have been filled with grout. The first face members overlying the face

the longitudinal members with 1-in. screw bolts as shown by the cross-section. Where nigger heads occur the screw bolts shall be 2 ins. in diameter and shall be long enough to pass down through the nigger heads and the two upper rows of cross-ties.

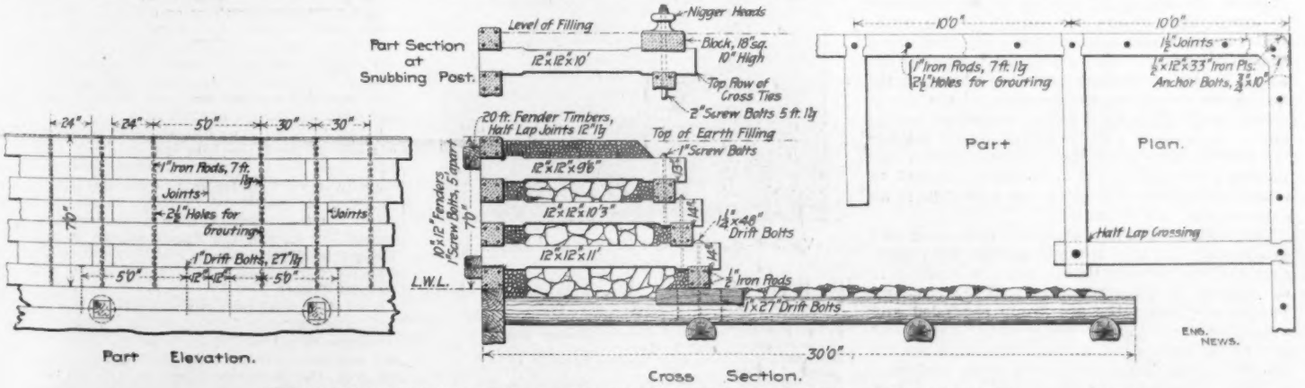
LONGITUDINALS.—The concrete members forming the longitudinals shall be molded in lengths of 20 ft. by 12 ins. square. They shall be secured to the cross-ties with 1-in. screw bolts in the manner shown by the cross-section.

STRENGTHENING OF MEMBERS.—All the concrete members in the superstructure shall be reinforced with iron rods incorporated into the member during the process of "casting." The rods, four in number, in each member, shall be ½-in. in diameter, and shall be long enough to extend the full length of the member and form a hook at both ends with a radius of 6 ins. They shall be placed at the four corners of the members about 2 ins. within the faces.

MOLDS.—A very rigid mold is required to form the members. These may be made of heavy timber or formed with channels of iron. The molds used will be subject to the approval of the Engineer-in-Charge. Great care must be taken in preparing the molds in order to cast the members in accurate dimensions and leave the holes exactly in the right place, to form a perfect contact with other members. The interior faces of the mold shall be covered with soft soap before "casting" each member.

MEMBERS.—After casting, the members will be given plenty of time to harden before they are disturbed in any way. They shall also be kept moist and covered until they have become very hard. It will be necessary to secure to them during the process of molding a couple of iron hooks to facilitate their handling when being put into the work.

The cribbing constructed as described is to be filled with stone, as indicated by the drawings. The specifications require that no stone over 2 ft. in diameter shall be employed and that the material immediately adjacent to the concrete members shall be stone broken to comparatively small size. The concrete beams themselves are to be made of a 1-2-3 mixture, with the stone broken to 1½ ins. or less, and with all the fine dust screened out.



DETAILS OF CONCRETE-STEEL CRIB-WORK WHARF AT DEPOT HARBOR, ONTARIO.

AN APPLICATION OF BAFFLE PLATES IN A FEED-WATER HEATER.

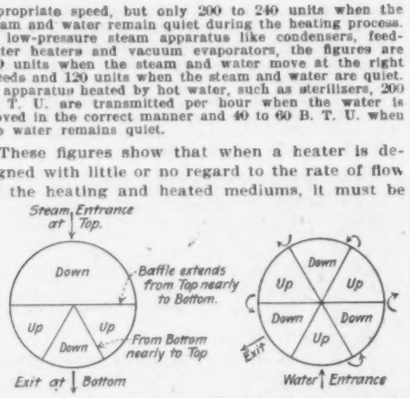
In the transmission of heat from a fluid to a metal surface, the rate of transmission, or the number of heat units passing per hour through a given unit area of surface, is directly influenced by the movement of the fluid over the plate surface. Where a rapid flow is secured, the rate of transmission may be several times as great as where convection currents alone are relied upon. The importance of this fact is not always appreciated as it should be in the design of feed-water heaters, surface condensers and similar apparatus.

We illustrate herewith, however, a feed water heater in which this principle has been effectively utilized. It was designed by the Blake & Knowles Mfg. Co., and has been named the "Multo-Current" feed-water heater. The accompanying diagrams show the general arrangement of the diaphragms in the interior of the heater. The following figures relating to heat transmission are furnished to us by the company:

The number of British Thermal Units passing through a square foot of thin copper per hour, with a difference of 1° F. between the warmer and colder mediums, is in the case of a high-pressure steam feed-water heater or evaporator, 400 units when the steam and water move at the

appropriate speed, but only 200 to 240 units when the steam and water remain quiet during the heating process. In low-pressure steam apparatus like condensers, feed-water heaters and vacuum evaporators, the figures are 300 units when the steam and water move at the right speeds and 120 units when the steam and water are quiet. In apparatus heated by hot water, such as sterilizers, 200 B. T. U. are transmitted per hour when the water is moved in the correct manner and 40 to 60 B. T. U. when the water remains quiet.

These figures show that when a heater is designed with little or no regard to the rate of flow of the heating and heated mediums, it must be



Baffle-Plates in Steam Space. Partitions in Heads Connected to Water Tubes.

Diagrams Illustrating Flow of Fluids in Feed-Water Heater.

considerably larger and therefore both heavier and more expensive than apparatus of the same output which is properly designed and constructed. This is of concern in stationary as well as marine service, since it determines the cost and weight of auxiliaries. Therefore it is important in the selection of a heater that the heat-transferring efficiency be considered, and the statement that quantity of heating surface determines the capacity of a heater, is erroneous. The steam should traverse each section at high speed and the streams should be frequently intermingled before leaving the heater. The feed water should do the same.

In the feed-water heater, illustrated herewith, five changes of direction of flow of the water have been adopted in order to obtain high velocity. The exhaust steam also flows through the length of the heater three times, the area of the passage being gradually reduced to allow for condensation. The steam enters through the upper opening and passes down through a passage of one-half the cross-sectional area of the whole heater, that is, there is a diametrical baffle plate extending from the top nearly to the bottom. At the bottom the steam turns upwards, traversing two segmental passages at either side, each having one-sixth of the total cross-sectional area; that is, there are two radial baffle plates back of the large diametrical baffle plate. Arriving again at the top of the heater the steam remaining uncondensed passes downward through a passage having one-sixth of the cross-sectional area of the heater and at the bottom the remaining steam and air escape through the discharge opening to the condenser or atmosphere, as the case may be. The water traverses six radial nests of tubes, each forming a segmental group. The cold water entering the heater passes up through the tubes occupying the last steam compartment. Arriving at the top, it passes down through the next segmental group, and so on, upward and downward until it reaches the outlet. This gives the rapid circulation and thorough mixing of the feed-water required to obtain the maximum heating effect possible in an apparatus of this character.

The tubes are easily accessible for cleaning, and special care has been taken to provide for expansion and contraction, thus making it possible to use copper or brass tubes as occasion requires. The ends of the tubes are firmly expanded and secured in the two heads, one of which is rigid and part of the main shell casting. The other head is bolted to a steel plate or diaphragm, the periphery of which is attached to the flange of the heater shell. This arrangement takes care of the unequal expansion between the tubes and the shell, and is free from strain under all conditions of temperature and pressure. The flow of water through the tubes is controlled by partitions in the water chambers at each end of the heater, so that the water will pass through each nest in turn.

The total absence of stuffing boxes and packings of any kind in this heater does away entirely with the possibility of leakage and loss of feed-water. The cross-sectional area between the tubes is greater than the area of the exhaust pipe, offering no obstruction to the flow of the steam and thus eliminating back pressure. Entrained water is removed by drip pipes. Access to the heater is had by removing the heads; the tubes of the vertical heaters can be cleaned from the top and the horizontal heaters from either end. Mud-blows are provided to keep the heater clean and free from sediment. Every heater is tested under 250 lbs. pressure per square inch, giving a safe working pressure of 175 lbs.

The following results were obtained in a test of one of these heaters of the vertical pattern rated at 125-HP.:

Exhaust openings, ins. diam.	8
Feed openings, ins. diam.	1½
Exposed tube surface, sq. ft.	24.05
Total quantity of feed water passed through heater per hour, lbs.	6,857
Initial temperature of feed water at entrance, Deg. F.	55
Temperature of feed after passing through first nest of tubes, Deg. F.	118

Vertical-Multi-Current Feed-Water Heater of 800-HP.

Designed and Built by the Blake-Knowles Steam Pump Works, New York.

Temperature of feed after passing through second nest of tubes, Deg. F.	155
Temperature of feed after passing through third nest of tubes, Deg. F.	170
Temperature of feed after passing through fourth nest of tubes, Deg. F.	190
Temperature of feed after passing through fifth nest of tubes, Deg. F.	195.8
Final temperature of feed after passing through sixth nest, Deg. F.	203
Rise in temperature of feed water, Deg. F.	148
Temperature of steam leaving the heater.	206
Heat absorbed by the feed-water per hour, B. T. U.	1,014,836
Heat absorbed per sq. ft. tube surface per hour B. T. U.	42,186
Velocity of water through tubes per min., ft.	125

On the basis of the ordinary commercial rating of one-horse power capacity per every 30 lbs. feed-water heated, this test shows that a heater containing 24.05 square feet of tube surface is capable of handling 228 horse power. This would reduce to 9.5-HP. per sq. ft. of tube surface which is over three times better than the commercial rating of 3-HP. per square foot.

ALTERNATING CURRENT SIGNALING FOR ELECTRIC RAILWAYS.*

By J. B. Struble.†

The scheme of alternating current signaling was devised to meet the demands of high-speed electric trains. Ordinary direct-current track circuits as applied to steam roads would not be satisfactory for this service because the running rails are here used as return conductors for the motor current. This current would wrongly affect the operation of the track relay, and of course the signal. To overcome this difficulty it was necessary to employ a current for the track circuit which would have such characteristic difference from that of direct-current as would operate selectively upon the track relay. Alternating current accomplishes this because of its ability to induce a current in another circuit brought within its magnetic field, a property not possessed by direct current. The track relay is, therefore, of the induction type, and responds to alternating current and not to direct current. An excess of direct-current cannot cause a wrong operation of the signal, other than to cause it to go to danger, for if a fuse or other protective device fails to open the circuit, the relay coils will be destroyed. With this relay there is no such thing as residual magnetism, and the points of pick-up and the release are identical, except as affected by twice the mechanical friction of the moving parts.

Two main feed wires bearing alternating current at, say, 60 cycles and 2,000 volts, extend the length of the system, and across these are connected the primaries of the track transformers, the secondary leads of which are connected across the rails at the exit end of each track circuit. Across the rails at the entering end are connected the terminals of the induction relay. We now have a circuit consisting of the secondary of the transformer, the rails and the coils of the track relay. Through this circuit pass simultaneously two kinds of current, alternating induced by the primary of the transformer, and direct, the return from the car motors.

Since the direct-current tends to make ineffective the alternating current, an impedance coil is connected across the relay terminals, or track rails; this has low ohmic resistance, but high inductive resistance or impedance to the passage of alternating current, and serves the purpose of shunting the direct-current from the relay, while compelling the alternating-current to pass through the relay.

It was my good fortune to be sent to California about a year ago to install the first alternating-current system of signaling. This was on the North Shore Ry., running north from San Francisco. The part signaled comprised about ten miles of double-track. This includes the rather novel arrangement of an old narrow-gage railway having added to its old steam service the new standard gage electric service. This was done by applying standard ties and the addition of one running rail. The rail which was common to both gages was divided into block sections. Thus trains of either gage, and whether propelled by steam or electricity, would operate the signals. Current for moving the electric trains, as well as for working the signal system, was generated at the Colgate power house, distant about 180 miles, in the Sierras. The current was transmitted at about 40,000 volts at 60 cycles to the local power house near the tracks, and there transformed to 4,500 volts.

For signal purposes we here connected to the neutral and one side of the three-phase system, giving about 2,300 volts single phase. At this voltage the electrical size of the wire required for the signal mains was less than that necessary for mechanical strength. In addition to supplying the track circuits, these mains served to supply current for lighting the signals and the way stations. The 6-c. p. signal lights, in that clear atmosphere, gave, with properly focused lenses, an illumination which was very satisfactory.

Some of the track circuits were about one mile in length, and as copious rains are frequent during the wet season, conditions were favorable for a test of the system. Ballast was of gravel and well removed from contact with the rails. We were happily surprised to find that under the worst conditions, the relays operated with a margin of about 30 to 40% or more, above the falling point. We had no failures due to the alternating current feature and since it was put into service, about eight months ago, we have not heard from the railway company, so the signals are presumably working in a satisfactory manner.

An interesting feature was that of the effect of the alternating current in the tracks, upon animals. Although the voltage on the rails was about 8 to 14, horses soon refused to pass over the tracks at road crossings,

*Abstract of a paper read before the Railway Signal Association at the May meeting in New York.

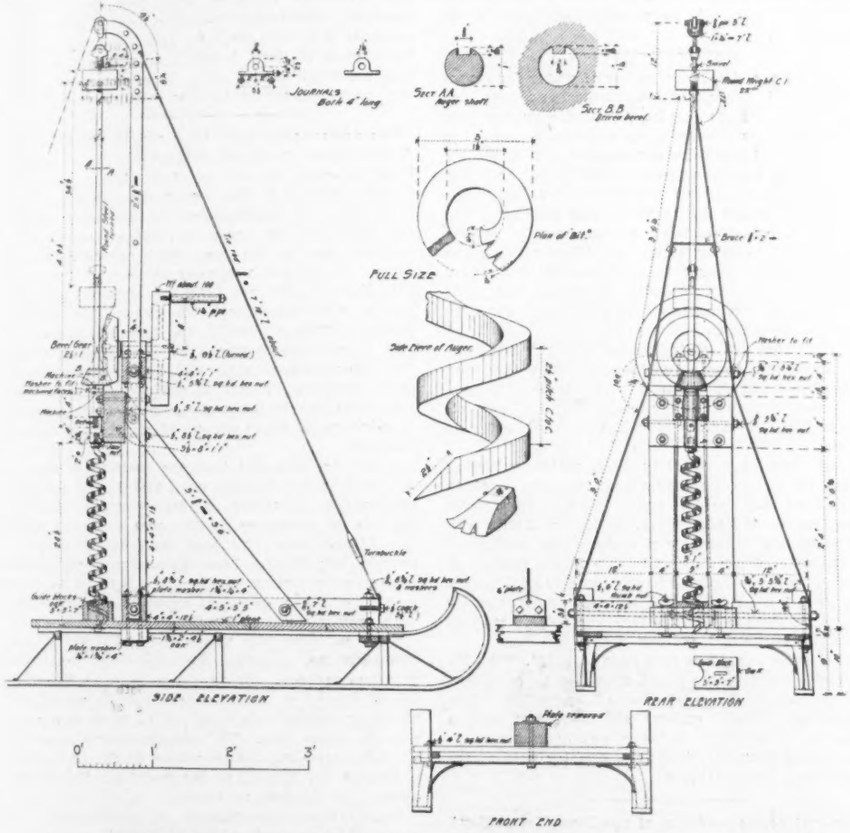
†Union Switch & Signal Co., Swissvale, Pa.

and things came to such a pass that something had to be done. The simple remedy was that of insulating the block rail at crossings and connecting over by a wire run through the road in grooved lumber.

The signals used were of the Union electric semaphore type, operated by 8-volt storage batteries, two sets of which were set in the base of the signals. Where two signals were opposite each other, one set served for both. They were charged at a rate of 1-5 ampere, through resistance, from the 500-volt contact rail. Thus no primary batteries were necessary, the chances of failure were reduced and the cost of maintenance also reduced to a minimum. During certain hours of the night the electric train service was shut down, while the steam service continued. Storage batteries thus kept the signals alive while the contact rail was dead.

BORING SOUNDING HOLES THROUGH ICE.

In taking soundings through thick ice, it is first necessary to make a hole through the ice, and this operation is frequently laborious and time-consuming. In Engineering News of Oct. 11, 1894, Mr. Joseph Ripley described an ice auger and the detailed method of using it in connection with the



DETAILS OF ICE AUGER FOR BORING SOUNDING HOLES THROUGH ICE.
Department of Public Works, Ottawa, Ont.

U. S. improvements of the St. Mary's River; and he incidentally notes the expense and difficulty attending the older methods of chopping these holes with an axe.

In answer to the query of a correspondent in our issue of Feb. 18, S. J. Chapleau, C. E., of the Department of Public Works, Ottawa, Canada, sends the following information relating to a machine for boring holes through ice for making soundings.

This machine was designed for ice not over 25 ins. thick, but by fitting it with a higher A-frame and a longer shaft the auger may be easily driven through 5 ft. of ice. If there are many holes to drill, a horse and driver to move the sled, a man to turn the auger and another man to handle the fall constitute the necessary force.

The best record made with this machine was 840 holes in seven actual working hours, in a 50 × 100-ft. "layout," and through ice varying in thickness from 12 to 22 ins. This is an average of two holes per minute. In this case the conditions were very favorable, as there was no snow or water on the ice and the weather was mild and clear. With 2 ft. of wet snow and slush on the ice, 210 holes were bored in 4½ hours through 14 ins. of ice; the "layout" was 50 × 50 ft.

As will be noted from the drawing, the auger and the A-frame are easily removed, and with the shaft lowered and the union secured so as to prevent the bending of the shaft, the whole machine is ready for shipment. It is quickly assembled again when wanted for use. The guide blocks preserve the alinement of the auger, which is liable to become strained at the jam nut if operated with one sled runner much higher than the other. For ice 6 ins. or less, or for "pack ice" of great thickness, the broad-bladed ice chisel is more efficient. The cost of the machine as illustrated is $78. The following notes relate to details of its manufacture:

The auger is fastened to the shaft by means of a thread and jam nut on its shank. The auger is made by bending a bar of ¾-in. square tool steel in a spiral around a bar of 1½-in. round iron; lead of spiral to be 2½ ins. c. to c. The lower end is drawn to a chisel edge, which is widened to 13-16 in., so as to clear both the inside and outside of the spiral. Great care is to be taken in sharpening the auger, as one stroke of the file will change the edge so as to make it quick or slow cutting. (Engineering News, 1894, Vol. II., p. 288.)

In addition to the above it is recommended that the core of round iron upon which the auger is to be wound be 1⅝ ins. diameter centered in a lathe and turned to 1⅛ ins. diameter, the core marked for lead, and the spiral wound by the lathe. When cold the outside face of the spiral should be trued to 3 ins. diameter or slightly less in the lathe. The core can be removed by heating the spiral.

The cutting edge should be widened as shown; 7-16-in. inside inner face and 1-16-in. outside outer face of spiral and toothed as shown to break up ice while cutting. No ice core will remain with this bit.

The bit should be drawn to a fine temper to at least the limit of bevel. Keep the upper bevel of the bit uniform and sharpen only the under face of the cutting edge, using a fine file. The desired efficiency is only obtained after repeated trial. Only two or three careful strokes of the file are necessary to re-sharpen.

THE CHARLES RIVER BASIN PROJECT, at Boston, has been approved by the War Department, and the construction of the dam, lock and drawbridge, and the dredging of canals and channels can now be proceeded with. The estimated cost of this work is $3,000,000. It will be in charge of the Charles River Basin Commission, consisting of President Henry S. Prichett, of the Massachusetts Institute of Technology; Hon. Henry D. Yerxa, of Cambridge, and Hon. Joshua B. Holden, of Boston. The Chief Engineer is Hiram Allen Miller, M. Am. Soc. C. E. The purpose of the improvement is largely to eliminate the objectional features due to low-tide stage in the Charles River. The proposed dam will maintain a substantially permanent water level, and converts this portion of the river into a lake of about 1,000 acres, adding much to the beauty and to the sanitary condition of the two cities. The dam will practically occupy the site of the present Cragie bridge; will be 100 ft. wide on top, and it will be provided with a lock about 350 ft. long, 40 ft. wide and 13 ft. deep. The dam will probably be made by filling in between heavy granite walls.

THE IRON AND STEEL INSTITUTE OF ENGLAND, has announced the names of the young men who have won the Andrew Carnegie Research Scholarships for 1904. These are: John D. Brunton, now manager of W. N. Brunton & Sons' Wire Mills, Musselburgh; Henry C. H. Carpenter, Assistant in Natural Physical Laboratory; E. G. L. Roberts, demonstrator in the last-named institution; E. A. Wraight, demonstrator at Royal School of Mines; Frank Rogers, B. Sc., of Cambridge University; Walter Rosenhain, scientific adviser to Chance Bros. & Co., Birmingham; Octave Boudouard, demonstrator of chemistry at the College of France; Pierre Breuil, Director of testing laboratory at the Conservatoire des Arts e. Metiers; Percy Longmuir, Assistant in the National Physical Laboratory.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a head-on collision between two freight trains on the Delaware & Hudson R. R. near Lanesboro, Pa., on May 20. A mistake in train orders is given as the cause of the accident. One person was killed and several were injured.

AN OPEN SWITCH at a siding in Monroe, Wash., caused the wreck of a Great Northern express train on May 16. Two men were killed and three were injured. It was found that the switch lock had been broken and the switch opened by two young boys.

A FOUR-CYLINDER BALANCED COMPOUND locomotive of a design differing from any of those described in the three articles in our issue of March 31, has been built for the New York Central Ry. and will be exhibited at St. Louis. It is of the Atlantic, or 4-4-2, type, with inside high-pressure cylinders, 15½ × 26 ins., placed in front of the saddle and driving the crank axle of the first drivers. The outside low-pressure cylinders are 26 × 26 ins., formed in the cylinder saddle in the usual way, and driving the rear coupled axle. Each cylinder has its own piston valve, but those of each pair of cylinders are mounted on the same stem, so that only two valve gears are required, as in a simple engine. The driving wheels are 6 ft. 7 ins. diameter, and the engine weighs about 200,000 lbs., with about 110,000 lbs. on the drivers. The engine was designed by Mr. F. J. Cole, Mechanical Engineer of the Schenectady Works of the American Locomotive Co.

SMOKE PREVENTION IN ST. LOUIS is reported as follows by Chief Smoke Inspector Chas. H. Jones in a pamphlet printed by the Civic Improvement League of St. Louis:

There are now 1,132 boiler plants in the city containing 2,041 boilers, aggregating 249,512 rated HP. Of these 859 use smoke preventing devices, divided up about as follows:

570, or 66% use steam jet and air blast devices.
196, or 23% use down draft furnaces.
37, or 4½% use fire-brick arches.
32, or 3½% have changed from steam to electricity.
12, or 1½% use automatic stokers.
12, or 1½% use smokeless fuels.

In addition, 273 plants, mostly small or heating plants, have no special devices, but are making satisfactory smoke records by reason of good common settings and skillful firing; of the above number, 207 run longer than 12 hours daily. The heating plants may be expected to shut down in a few weeks, and as these make considerable smoke, and are often hard to handle, the effect on the atmosphere will be noticeable.

Gratifying progress is reported from locomotives and steamboats, the management of all lines assuring the city of their desire to co-operate with them, and reporting just what they are doing. There has been an appreciable reduction in smoke from this source.

On the legal side of the work, there have been 123 prosecutions in the Court of Criminal Correction. Of the above number 57 pleaded guilty and were fined $25 or more, and costs, which ranged from $15 to $50 on each.

With the exception of a small number, all the parties prosecuted have since greatly reduced their smoke. Only about a half dozen parties have been brought into court more than once. One offender has been in court three times, and is now slated for the fourth. Another four times, and is now up for the fifth time. The last mentioned offender claims that he can better afford to pay $50 a month and costs, than to be bothered with smoke consumers. Evidently he needs enlightenment.

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ADVERTISING RATES: 20 *cents a line. "Want" and "For Sale" notices, special rates, see pages* 26-27. *New copy for standing advertisements should be received ten days in advance of publication; new advertisements, Monday morning. The pages containing "Want" advertisements are held open until Tuesday, and those with "Proposal" and "For Sale" advertisements until Wednesday at* 11 *a. m.*

We give up much space in this week's issue to a paper on the art of softening water which constitutes, we believe, the best treatise on this subject that has ever been written. It is a subject, moreover, which is of immediate interest to American engineers and is destined to be of much greater importance in the future than in the past. Hitherto in this country the chief work in water softening has been done by the railway companies in connection with the purification of water for locomotive boilers, although in recent years owners of stationary steam power plants have undertaken to reduce their bills for coal and for boiler repairs by installing water softening plants.

We are strongly of the opinion, however, that the great field for water softening is in the treatment of the entire supply of a municipality, and that the Winnipeg plant, described by Mr. Handy in this issue, is destined to be the first of a large number of American municipal water softening plants.

Of course the larger cities, which take water from surface streams, secure generally a fairly soft supply, and for them water softening is never likely to be demanded; but the case is otherwise with many of the smaller cities. As we have recently pointed out, the reaction from the use of sewage polluted streams for water supplies and the popular demand for pure and safe water is bound to lead to the more general use of underground supplies in places of moderate size; and in a very large proportion of cases this underground supply will be found to be more or less hard. The problem which was presented at Winnipeg two or three years ago is exactly similar to the problem which dozens or hundreds of American cities must face. Shall the water supply be taken from a surface stream, more or less subject to pollution, which pollution is quite certain to increase year by year, with the growth in density of population, or shall water from driven or bored wells be used, absolutely free from organic impurities, but more or less heavily charged with minerals?

In the past, when the public was ignorant of the dangers of polluted water, the surface supply has had the preference. In the future, public opinion is pretty sure to be on the side of the underground supply.

The general hardness of well-water supplies is without doubt a very serious objection. The objections of steam users to hard water are well known and are bound to carry great weight in every city desiring to attract manufacturers. But the bills for steam boiler repairs are not the chief objection to a hard water supply. The necessary increased consumption of soap due to the use of hard water lays a tax on every family which in the aggregate amounts to an annual burden far in excess of the amount paid by the owners of steam plants in added cost of boiler cleaning and repairs, at least in the ordinary community.

If the use of this hard water were a necessity the expense might be borne; but it is not a necessity. It is entirely within the power of the chemical engineer to remove the minerals from the water and to do it at a cost which is very small in proportion to the benefit conferred. It is shown that at Winnipeg water is being softened at a total outlay of from 2⅓ to 3⅔ cts. per 1,000 gallons. This means that to supply a family using 50,000 gallons of water per annum with soft water instead of hard water would cost between one and two dollars a year and the family would save many times this amount in soap and other laundry expenses.

Turning now to the softening of water for steam boilers and other manufacturing purposes, we wish to emphasize the idea that the proper way to soften water economically is to work on a large scale. When the railway companies first undertook to deal with the serious troubles due to boiler scale, the favorite plan was to use so-called "boiler-purges" in the feed water. The next step was to treat the water at the water station and get rid of the scale-forming impurities before putting the water into the boiler. Instead of making a water softening plant of the locomotive boiler, one plant at the water station provided soft water for dozens of locomotives.

In the case of isolated water stations, the railways can of course go no further; but where they take their supply from city water-works, they may well use their influence in favor of municipal softening plants and will find it economy to do so.

The larger the capacity of a water softening plant, the better the supervision that can be given it, and the more perfect and economical the results that can be secured. Water softening cannot well be made an automatic process. The variations in the rate of working and often in the quality of the water treated, demand the close attention of a competent attendant, and this is almost equally true whether the plant is treating 100,000 gallons daily or 10,000,000 gallons.

The Winnipeg plant is a case in point. The labor of operating the plant amounts to one-third to one-fourth the total cost of operation, when softening 1,500,000 gallons per day. But with a plant only one-tenth as large, nearly as much labor would still be required if equally perfect results were to be attained.

Several correspondents of the New York "Sun" have lately been criticizing the graduates from the West Point Military Academy, charging that these graduates lack aggressive initiative and but a small proportion of them ever gain success in civil life. To these strictures Col. Charles W. Larned, U. S. A., now a professor at the Academy replies by compiling from the records of the Academy an interesting tabular statement of the civil occupation of graduates up to 1903. This list includes one President of the United States and one President of the Confederate States, 14 ministers to foreign courts, 24 members of the U. S. Senate and House of Representatives, 171 U. S. civil officers of various kinds, 16 governors of states and territories, 77 members of state legislatures, etc. Among other occupations and professions, we find 136 professors and teachers, 14 chief engineers of states, 87 presidents of railway and other corporations, 62 superintendents of public works, 63 chief engineers of railways, etc., and 228 civil engineers. Our interest lies in the fact that civil engineering seems to be the favorite profession of those graduates who for some reason retire from the army. And this is natural enough as engineering enters largely into their professional training at the Academy. Among the other professions entered in civil life, the next to engineering is that of the practice of law, 200 lawyers figuring in the list presented by Col. Larned; though 230 are farmers and planters, and 179 are noted as authors. The table also includes one bishop and one superior-general of a clerical order, 20 clergymen and 14 physicians. Only 77 became manufacturers, but 122 are merchants. In a summary of this extended table Col. Larned selects 466, out of an aggregate of 2,371, who have reached a very fair degree of success and distinction. As this means nearly 19% of success in civil life alone—leaving out whatever signal success some of these men had previously attained in the military service, it would seem that a goodly proportion of these graduates must have at least as much aggressive initiative as those leaving other high-grade educational institutions; though in the later case the graduates have been especially trained for some particular civil occupation, and have had that advantage to start with. As a matter of fact the four years of training and discipline at the Academy, the splendid physical health and fitness resulting from this training, and the clean life and high sense of duty forming an integral part of this training, should well fit a young man for any civil occupation he may choose to follow.

The remarkably high duty record given by the Worthington pumping engines in the Central Park pumping station of the Chicago waterworks, reported in this issue, is worth a word of comment. An examination of the table giving the record of the tests in detail shows that in one test the duty attained much exceeded that in any of the others, reaching the notable figure of 174,735,801 ft.-lbs. per 1,000 lbs. of steam used (at 154 lbs. gage pressure). The reason for this exceptional duty is found in the fact that the steam was highly superheated, the superheating being 154°, as compared with 143° in the next highest test. Looking further it will be seen that the duty obtained in the several tests closely corresponded with the number of degrees of superheating.

It will be apparent that the method of stating the duty in foot-pounds per 1,000 lbs. of steam is particularly favorable to these engines since the degrees of superheat in the steam do not enter in. If the duty had also been stated in foot-pounds per million heat units delivered to the engine, as is frequently done, the figures for duty would not have appeared so high in comparison with previous, record-breaking tests.

Even as it is, this figure of 174,735,801 ft.-lbs. per 1,000 lbs. of steam does not quite reach the previous records. In our issue of Sept. 27, 1900, we published a table of recent high records in pumping engine tests in which three engines gave records above this. The highest record made by an Allis triple-expansion engine at St. Louis, was a duty of 179,450,000 ft.-lbs. per 1,000 lbs. of dry steam (at 126 lbs. pressure).

Nevertheless, the figures of performance of these Chicago engines are of decided interest as showing what very high economy it is possible to attain with direct-acting duplex engines not controlled by a flywheel, by the simple expedient of superheating. As we have before pointed out in these columns, the practical economic value of high duties rapidly falls off as the economy of the engine increases. The difference in coal consumption between an engine with a 50,000,000 duty and one with a 75,000,000 duty is such that the more economical engine is worth much effort to secure. The difference in coal consumption between a 150,000,000 duty and a 175,000,000 duty on the other hand, becomes so small that other considerations than mere fuel economy are apt to determine the choice of a machine.

The oldest civil and mechanical engineer in the world who is still actively engaged in practising his profession is without doubt Mr. Charles Haynes Haswell. At the advanced age of 95 years, Mr. Haswell continues regular work, very rarely missing a day from his desk in the engineering bureau of the Board of Estimate and Apportionment of New York city. Last Sunday,

May 22, was Mr. Haswell's 95th birthday, and on Monday evening the event was celebrated by a dinner tendered to this veteran engineer by members of the Engineers' Club of New York city, with 65 covers laid. As was proper in a dinner given in honor of a man who held the first commission as Engineer-in-Chief of the United States Navy, under the Act of Congress formally creating this office, the Steam Engineering Corps of the Navy was largely represented at the dinner. Admirals Melville and Loring, both of whom have served with distinction in the office first held by Mr. Haswell, spoke of the evolution of the American steam navy and the part taken in its birth by their honored guest. Admiral Loring presented to Mr. Haswell, on behalf of those present, a massive silver loving-cup. In replying, Mr. Haswell related some interesting reminiscences of 1837, referring, among other things, to his suggestion to his then employer that some spare time on hand be devoted to the design and construction of a tow-boat. His employer objected strenuously to this misuse of time and money—for the reason that there were already two tow-boats in use in American waters and there was no room for another. Every engineer present extended his congratulations to Mr. Haswell; and in their congratulations we join, with the sincere hope that he may live to round out the century mark.

THE COPPER SULPHATE TREATMENT FOR PUBLIC WATER SUPPLIES.

Every engineer connected in any way with public water supplies will study with great interest the report which we print in this issue on the use of copper sulphate for the treatment of water supplies, a new process originated by Dr. Geo. T. Moore, of the U. S. Department of Agriculture. The newspaper accounts which have appeared regarding the discovery prior to its official publication have made such extravagant claims for the process that many conservative engineers have doubtless formed a prejudice against it, and will be inclined to doubt the claims made for it. For this reason we have deemed it worth while to present Dr. Moore's own statements quite fully.

The reader who carefully studies these statements will see at once that the process differs very greatly from what the original reports indicated. Instead of being a scheme for annihilating the typhoid bacillus or eradicating mosquito larvae it is actually, in its present stage, a method of eradicating certain forms of algae from city water supplies.

As most of our readers are aware, the growth of various forms of algae in water-works reservoirs has been one of the most prolific causes of trouble to those in charge of water supplies. While these algae constitute no such menace to health as does sewage pollution, they have caused, probably, a great deal more complaint from water consumers than all the typhoid pollution that has ever taken place. Water polluted with typhoid germs may be perfectly clear, sparkling and odorless. Water polluted with the results of algae growths is frequently so offensive to smell and taste as to be practically undrinkable. The water user, of course, judges the quality of the water by his senses; and if the water is offensive to taste and smell he immediately concludes that it is caused by pollution from the foulest sources. It would be impossible to convince him of the actual fact: that it is the purest water—that drawn from springs or wells or other underground sources, or that which has been thoroughly purified by passage through sand filter beds—in which these algae most flourish.

Certainly, if Dr. Moore's discovery will enable the water-works superintendent to prevent algae growths in his reservoirs, it is entitled to rank as the most important contribution to the art of water-supply engineering that has been made in many a long day.

It is worthy of particular notice, too, that this new discovery is likely to be of even more importance under the conditions of the future than of the past. We pointed out in these columns a month ago, in our issue of April 28, that the demand for pure and safe water supplies would make it necessary in the near future to make a much larger use of underground water supplies for places of moderate size than has been made in the past, and to thoroughly filter the water supplied to the larger cities or other places where an underground supply is unavailable.

But for storing these pure supplies we must go to the heavy expense of roofing over the reservoirs, which adds a considerable percentage to the cost of any filtration plant or well plant. If, now, there is available a simple and innocuous method of preventing the growth of these troublesome algae, the fact is of immediate importance in reducing the cost of purer water supplies and bringing nearer to realization their general introduction.

Turning now to Dr. Moore's report, let us see what he has actually shown. Briefly stated, it appears from his experiments that a number of algae known to be troublesome in water-works reservoirs can be eradicated by the application of a very minute amount of copper sulphate, say, one part in one million. This amount is far too small to cause any physiological effect on those who drink the water. If we estimate the average consumption of water at three pints per day, an individual drinking water containing uniformly 1 part in 1,000,000 of copper sulphate would consume only between seven and eight grains of the substance in a whole year. Besides this, where copper sulphate is used for treating algae-infested water, it enters into combination with the organic life, and is thus precipitated. Again, a single application, or, at most, two or three in a season, would doubtless be sufficient to eradicate algae, so that an individual would not actually receive in a year even the minute amount of the drug above computed.

It will be noted that the results thus far made public by Dr. Moore relate chiefly to laboratory experiments, which have been well corroborated, however, by the actual eradication of the alga Spirogyra from a Virginia watercress bed, and of the well-known Anabaena from a water-works reservoir in Kentucky. The success thus far effected is exceedingly promising and gratifying, but further experience on a large scale as well as laboratory tests with additional forms of algae will be desirable before the capabilities and limitations of the new method can be definitely stated.

It will be noted in the summary of Dr. Moore's laboratory tests that the different species of algae vary widely in their resistance to the toxic influence of copper sulphate. The Anabaena and Urogiena, which have given so much trouble to water-works managers, appear to be among the species most easily killed, a solution of one part to 3,000,000, or even less proving quickly fatal. Some other forms require as much as one part to 50,000, apparently, to destroy them, and one variety is reported to have required one part to 2,000.

Now the question of immediate interest to water-works engineers is: what resistance will other forms of algae present to the copper sulphate treatment? There are a number of the most troublesome varieties of algae on which no tests appear to have been made as yet. Asterionella, for example, is said by Whipple to produce the strongest odor of any of the algae, and has been particularly troublesome in the Brooklyn reservoirs. Crenothrix, while not responsible for bad tastes and odors, has caused a vast amount of trouble in places using ground water supplies. Tabellaria grows on the surface of sand filter beds and makes necessary more frequent cleaning. None of these are reported upon by Mr. Moore; and while there is good reason to hope that these species may be as easily killed as the Anabaena, there is, of course, a possibility that they may prove so resistant as to make the treatment with copper sulphate much more difficult.

Manifestly, therefore, engineers cannot abandon the precaution of roofing over reservoirs for filtered water or ground water until it is definitely known that all the species of troublesome algae will yield to the copper sulphate treatment. Doubtless with the publication of Dr. Moore's discovery, investigators generally will turn their attention to the task of testing its efficiency, and it will be given a practical trial on water-works reservoirs wherever trouble with algae occurs.

It may be that more extended practical tests will show that some of the other forms of troublesome algae can so resist the copper sulphate treatment that its use will not be practicable. Or it may be necessary to shut off the reservoir from use for a time while the treatment with the copper sulphate is going on and afterward treat the water with some other chemical to precipitate any copper sulphate remaining in solution. These and similar facts are still to be determined, as Dr. Moore recognizes in his report.

We point out these things with no intention to detract in any way from the importance and value of the invention. Enough has already been established to fully warrant its publication and to justify high praise to its originator. If the copper sulphate treatment can do nothing more than eradicate from reservoirs the troublesome Anabaena and Urogiena, it will still be a discovery of great value to the public.

Turning now to the part of Dr. Moore's report, relating to the treatment of drinking water with copper sulphate to destroy the typhoid and similar pathogenic bacteria, it will be seen by the reader of the report that this is still on an experimental basis. Nothing yet shown gives any expectation that copper sulphate or any other chemical treatment can replace the present well-known and accepted means of purifying drinking water, and the report definitely states this. What Dr. Moore has done is to show that the bacilli of typhoid and of cholera, when living in fairly pure water are killed by very much smaller percentages of copper sulphate than has hitherto been supposed effectual. A way has been pointed out for further experiment, with fair promise of success, looking to a treatment of water in a reservoir which may have become polluted with typhoid or cholera germs. Of course, this will be in the nature of an emergency measure. No precautions now observed to prevent contamination of a water supply or to purify water when contaminated, such as filtration or boiling are likely to be abandoned. It will be of value, however, to have at hand some measure by which the water supply on which a community relies may be made usable with less danger when pollution has occurred.

As for the medical treatment of typhoid patients with copper sulphate, that is a matter outside the province of this journal to discuss. It is however, gratifying to know that it appeals so favorably to the medical profession that experiments with it are at once to be undertaken.

One other subject discussed by Dr. Moore is worthy at least a word of comment, and that is the effect of metallic copper instead of copper sulphate upon bacteria and algae. His experiments showed that surfaces of clean metallic copper have a strong antiseptic influence upon water in contact with them. The result of Dr. Moore's experiments in this field are in harmony with the results of some experiments in a different field recently carried out by the New York Board of Health to determine the extent to which money in circulation might be the means of spreading disease. It was found that paper money carried bacteria in great amounts, and might well serve as a distributor of infection. Coins, however, and particularly those of copper, were found to possess strong germicidal power, so that even when covered with a culture of diphtheria or other germs, they become sterile within a short time.

This matter is a subject of much scientific interest and it may well be that further experiments will lead to a more general use of copper utensils such as soldiers' canteens for example, as an added safeguard against the spread of disease.

LETTERS TO THE EDITOR.

Filling Columns With Concrete.

Sir: In the construction of one of our mills we are using 6-in. wrought-iron columns ½-in. thick, and 21 ft. 6 ins. long. It has been suggested to us to fill these columns with concrete.

The writer has used concrete in cylinder piers 12 ins. diameter and ½-in. thick, but has never used concrete in anything less than 12 ins. diameter. Would you be so kind as to give us your opinion in regard to this matter?

Yours truly,

W. H. T, Engineer in Charge.

Greensboro, N. C., May 21, 1904.

(The concrete-filled column will be stronger,

stiffer, better able to resist fire, and more secure against internal corrosion. We have several times in these columns strongly urged the filling of steel columns with concrete and have yet to hear any sound argument against it.—Ed.)

Tests Desired of the Increase in the Supporting Power of Piles After Driving.

Sir: It is a well-known fact that piles, when left to stand for any length of time have their supporting power considerably increased through various causes. The law of this increase is an important matter in connection with the use of any pile-driving formula.

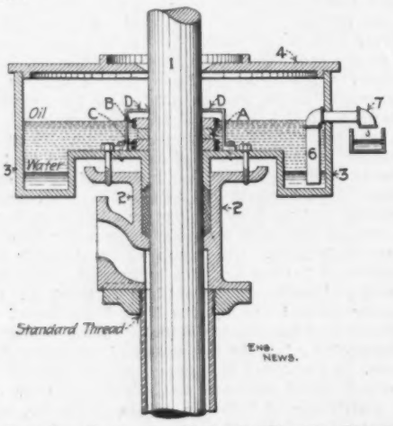
I would be greatly pleased if contractors and inspectors who have it within their power would test piles according to the following scheme, and submit the data to me directly, or preferably through the columns of your magazine. By so doing, it is believed valuable information will be obtained, which I will gladly collate and publish for the benefit of the profession.

Length of pile.
Depth and kinds of materials penetrated.
Weight of hammer,
Height of fall for last blow,
Corresponding penetration,
Date and time of test,
Penetration under similar conditions, approximately 1 h. later,
Penetration under similar conditions, approximately 12 hrs. later.
Penetration under similar conditions, approximately 24 hrs. later.
Penetration under similar conditions, approximately 3 days later.
Please give exact date and time of each test and actual fall and penetration observed.

Yours very truly,
E. P. Goodrich, Chief Engineer.
Coffee Exchange Building, Hanover Square, New York.
May 18, 1904.

A Lubricating Device for Hydraulic Elevator Plungers.

Sir: The design herewith is submitted for the benefit of your numerous readers who were kind enough to investigate the matter sufficiently thoroughly to prompt them to inquire: "How can you attach a liquid lubricator, the subject of your article in the March 24th edition of Engineering News, to a plunger elevator whose port is cast, with the stuffing box, in the upper section of the cylinder?"



Lubricating Device for Hydraulic Elevator Plunger.

Like numbers and letters refer to the same parts and the previous description remains unchanged.

The cut, which explains itself to those interested, represents the plunger of a hydraulic elevator, a section being taken through the stuffing box showing port cast in upper cylinder section. The liquid-tight cylinder 3, may be cast with, or form a part of, the stuffing box gland, thus overcoming the many difficulties and disadvantages which were evident in the previous sketch.

Respectfully submitted,
Edward Van Winkle, Consulting Engineer.
100 Fifth Ave., New York, April 27, 1904.

What "Gumbo" Is.

Sir: In reply to your inquiry as to "gumbo," I would say that the following expresses my idea of it:

"Gumbo" is a black organic soil. When wet it is oily, yet sticky. Try to grade in it, and if wet it sticks together in large masses; if dry it is nearly as hard as shale rock; takes a four to six horse plow to break. It is in a class by itself. Used dry makes a good ballast for track; wet, the track sinks out of sight.

It has all the bad qualities of clay, magnified, and few of the good qualities. It has been suggested that its soapiness is the result of the alkali in it, as it generally occurs in country where the soil is of that character.

Yours truly, P. E. Green.
Huron, S. D., May 16, 1904.

Sir: Hoping that this will aid "R. W. M." in his classification of "gumbo," will say that the "gumbo" or "buckshot," as found in the bottom lands of the Missouri and Mississippi rivers, respectively, is a dark colored clay of a very tenacious nature; so much so that mud of this material can scarcely be brushed from clothing after being allowed to dry, but must be scraped off, usually taking the nap of the goods with it. When slightly moist, or after having been subjected to a light rain, it cannot be handled economically with ordinary tools, as it balls up and clogs the same, requiring frequent cleaning by some mechanical means, while in ordinary clay these tools will work clean under conditions much more unfavorable; possibly this fact is due, not as much to a difference in the real clay in each case, as it is to an almost total absence of sand and loam in much of the "gumbo" as compared with the material classed as ordinary clay in other sections of the country.

"Gumbo" will permit a certain quantity of sand to settle through it, and a small layer of sand placed on top will, in a few years, entirely disappear below the surface. This property doubtless explans why we usually find a less amount of sand in this kind of clay.

Were your correspondent located in the lower Mississippi Valley, where this clay is called "buckshot," and were he to call for "gumbo," he would be given a plate containing a mysterious looking mixture, described in the Century Dictionary as "A soup, usually of chicken, thickened with okra." After having thoroughly "classified" this "gumbo" he will never care to tackle any other variety.

Yours very truly Chas. H. Miller.
727 East End Ave., Pittsburg, Pa.

Rapid Corrosion of a Steel Stack.

Sir: A steel stack 30 ins. in diameter by 60 ft. high, serving a 100-HP. boiler using Pocahontas coal, is found to corrode rapidly at about the middle of its height. The stack is made of No. 10 sheet steel and its average life is about two years. The lower third is least corroded, so that it is used to make the upper section of the new stack.

What can your readers suggest to protect the interior of the stack from corrosion. No very heavy lining may be used as the stack rests directly on the breeching of the boiler. Is there any paint or other coating which will give a fair degree of protection? Will a Portland cement coating be of any service? Will an iron chimney be better than a steel chimney? It is presumed that the corrosion is due principally to sulphur gases from the coal, but I do not know why the corrosion should be more rapid at the middle of the height than near the bottom. The boiler itself does not seem to suffer by corrosion. It is about twelve years old and has never needed a new tube. Pocahontas.
May 18, 1904.

(The probabilities are that the corrosion occurs at the point where the gases become cooled to the point of condensation. Above this temperature, furnace gases even from coal high in sulphur cause little corrosion; but as soon as they are cooled to the point where the sulphur vapor is condensed there will be very vigorous corrosion.

If any of our readers are wise enough to know of any coating which will protect the above chimney, we trust they will make haste to spread their knowledge before their professional brethren in our columns. It will benefit not only our correspondent, but the users of economizers and others who have to contend with the corrosive effects of condensed flue gases.

Meanwhile, we would suggest that the stack had better be set on a more substantial base than the breeching of the boiler and be given a good brick lining. This will probably keep the gases warmer, so that condensation will not take place inside the stack.—Ed.)

THE INTERNATIONAL GOOD ROADS CONVENTION.

The good roads convention held at St. Louis, Mo., from May 16 to 21, was one of the most successful and largely attended of the conventions which have been held during the past few years under the auspices of the National Good Roads Association. A session was held each day from 10 till 1, and all the sessions were attended by large numbers of delegates, who followed the proceedings with active interest. There was some attempt to inject politics into the matter, and a good deal of the talk was irrelevant, but the convention as a whole indicated that the movement is growing in importance, that the importance of the road question is being much more widely recognized, and that various attempts at improved conditions are being made, and may be concentrated upon some definite line of action.

The convention was called to order by Mr. W. H. Moore, President of the National Good Roads Association, who remarked that the movement started in Missouri 14 years ago. The opening address was delivered by Hon. A. M. Dockery, Governor of Missouri, who spoke of a system of good roads as necessary to supplement the great systems of steam railways and of interurban and rural electric railways. He also considered that such a system of roads would be of as much importance to the cities and the manufacturing industries as to the rural districts. Mr. H. H. Wernse, President of the St. Louis Merchants' Exchange, delivered an address on "The Commercial Advantages of Good Roads," dealing with the matter in a very general way, and advocating government aid. He estimated the average load hauled in a country wagon as one ton, and proceeded to show how much the farmer could save if he had roads on which he could haul two tons to the load, getting his produce to the market more quickly and giving him more time to attend to work on the farm.

A speech very much to the point was made by Mr. W. H. Moore, President of the Association, who started out by saying that people in the Mississippi valley are "in the mud" for four or five months of the year. A great amount of money is spent on road work, but with very poor results, as most of it is wasted through lack of competent men and intelligent methods. In Missouri alone $2,700,000 have been spent by about 5,000 road supervisors, with little or nothing to show for the expenditure. He strongly favored the employment of convicts and vagrants upon the roads and in the stone quarries, and stated that the labor organizations favored such a system. The movement for good roads must begin with a local organization, to be followed by state aid and then by national aid. It should not begin with an application for national aid when (under present methods) this would mean simply a greater waste of money than at present. He also advocated the establishment in each state of a state highway commission with engineering assistance, and submitted a draft of a bill for a state engineer and state aid for roads, based on the law now in force in Arkansas. An abstract of this bill, presenting its essential features, is given below:

BILL FOR A STATE ENGINEER AND STATE AID FOR ROADS.

(1) The Governor shall appoint as State Engineer some competent and experienced civil engineer of firmness, energy and good character, who shall be chosen solely with a view to his fitness and without reference to his politics or to his residence at the time of his election.

(2) In addition to his other powers and duties, the State Engineer shall: (A) compile statistics relative to the public highways throughout the state and collect information in regard thereto; (B) shall investigate and determine upon the various methods of construction and maintenance of roads and bridges, adapted to the different sections of the state; (C) may be consulted at all reasonable times by county, city or other officers, having care or authority over highways and bridges, and he shall advise them relative to the construction, maintenance, alteration or repair of the same; (D) he shall send out to the county judges, road commissioners and road overseers, from time to time, practical literature relating to roads and highways; (E) he shall make careful tests of all road material sent him for examination and make a full report thereon, and the cost of transporting said material for examination shall be borne by the state; (F) he shall quarterly make and publish a report, giving full information (and as far as possible without the use of technical terms) to the various stone and other road materials in the state examined by him and their suitability for road making; also make reports of the roads or parts thereof built or improved under his direction the preceding quarter, their location, cost, and the manner of improvement, and such other facts as may be useful in the improvement of the highways; (G) he shall at each regular session of the legislature make to it a like report covering the period of his services since its last regular session; (H) he shall at least once in each year hold or cause to be held in each county a public road meeting, and at such meetings shall distribute road literature, stimulate interest in road improvement and give or cause to be given practical lectures and instructions in the building of permanent roads.

(3) Any five or more residents along any public road, lying outside the boundaries of any city or incorporated town, may file their petition in duplicate, duly verified, in the office of the county clerk, asking for the permanent improvement of said road or any portion thereof, alleging that they will provide 15% of the total cost of the improvement. They shall attach to said petition a plat of the road or section thereof sought to be improved. Notice of said petition, with the purpose thereof, signed by said petitioners, shall be published in some newspaper of the

county at least 10 days prior to the next regular term of the county court.

(4) The court shall proceed to hear said petition; and, if the levying or county court, last preceding, shall have made an appropriation for building and repairing public roads and bridges and the condition of county revenues justifies the expenditures necessary to make the improvements prayed for, the court shall grant said petition, and shall forward immediately one copy of said petition and plat, together with his order, to the State Engineer.

(5) The State Engineer shall examine said petition and plat and determine whether or not the proposed improvement is of sufficient importance to justify the necessary cost thereof, having in view the use, location and value of such highway or section thereof, for common traffic and travel, and if he approves the petition shall so order, such engineer shall cause the highway or section thereof therein described to be mapped both in outline and profile. He shall then indicate how much of said highway or section may be improved by deviation from the existing lines whenever it shall be deemed of an advantage to obtain a shorter or more direct road without lessening its usefulness, or whenever such deviation is of advantage by reason of lessened gradients. He shall also cause plans and specifications of such highways or sections thereof to be thus improved to be made for telford, macadam or gravel roadway, or other suitable construction, taking into consideration the climate, soil and material to be had in the vicinity thereof and the extent and nature of the traffic likely to be upon such highway, specifying, in his judgment, the kind of road a wise economy demands. Improved or permanent roadways of all highways so improved shall not be less than 8 ft. nor more than 16 ft. in width, unless for special reasons, to be stated by such engineer, it is required that it shall be of greater width.

(7) Upon the completion of such maps, plans and specifications, the State Engineer shall cause an estimate to be made of the cost of construction of the same, and transmit it to the county judge.

(8) The county judge shall notify the petitioners by letter and publish a notice in a newspaper of the granting of said petition, and that he has the plans and specifications of said proposed improvement at the office of the county clerk for inspection. Within 90 days after said notice the petitioners shall place in the county treasury to the credit of said road, subject to the orders of the county judge, as hereinafter provided, 15% of the engineer's estimated cost.

(9) Within ten days after the 15% has been secured the county judge shall certify this to the State Engineer, and that the work is ready to proceed.

(10) The State Engineer shall then advertise for bids for two successive weeks in a newspaper published in the county seat, and in such other newspaper as shall be deemed of advantage, for the construction of such highway or section thereof, according to such plans and specifications, and award such contract to the lowest and best responsible bidder, and he may in his discretion, and that of the county judge, award the contract to the county or to some board of persons acting officially for the county or road district in which said improvement may lie; but no contract shall be awarded at a greater sum than the estimate. But if no bid otherwise acceptable be made within such estimate, such State Engineer may amend his estimate and certify the same to the county judge, and upon the deposit of any additional sum necessary to make 15% of such amended estimate, proceed anew to obtain bids and award the contract. Partial payments may be provided for in the contract and certified to by such State Engineer to an amount not to exceed 80% of the value of the work done, 20% of the contract price being retained until the entire work has been accepted. Such State Engineer shall have some competent person to superintend and have engineering supervision of such work.

(11) Half of the expense of construction shall be paid by the State Treasurer upon the warrant of the Auditor, issued upon the requisition of such engineer out of the appropriation made to carry out the provisions of this act, but no such construction or improvement shall be undertaken in any one year the cost of which with other such work previously done or undertaken shall exceed the amount appropriated for that year under the provisions of this act. And 35% of the expense shall be a county charge and shall be paid out of the general fund of said county after presentation and allowance in the same manner as is provided for the filing and allowance of other claims against the county, but such claims shall have been approved by the State Engineer; and the remaining 15% shall be paid upon the order of the county judge out of the fund deposited for that purpose as hereinbefore provided.

(15) No street surface railroad shall be constructed upon the portion of a highway which may be improved under the provisions of this act, except upon the consent of and under such conditions and regulations as may be prescribed by the State Engineer.

WORK OF THE ROAD ENQUIRY OFFICE.

Mr. Martin Dodge, Director of the Office of Public Road Inquiries, U. S. Department of Agriculture, made an address on the subject of "Educational and Experimental Work of the Government Division of Roads." He opened by estimating the cost of transporting freight on the roads at 25 cts. per ton per mile, as compared with 8 to 12 cts. in other countries. In the past, bills for road improvement in the northern states have been defeated by the farmers because all the expense would have been thrown upon them. There is now, however, a general sentiment prevailing among the farmers and the people at large in favor of road improvement, and it now remains to develop this sentiment into practical form. All early road laws were based on the principle that the people of the rural districts should pay all expenses for road improvement, and so far this has been changed in but few states. But the entire population derives benefit from good roads, and should be taxed for them, and Mr. Dodge felt that at the present time the people, the manufacturers, the railways, etc., are quite willing to assume their share of this cost.

The Department of Agriculture has had this matter in hand for 11 years, and has done a considerable amount of educational work by preparing and distributing literature, and by furnishing special information in reply to the inquiries which are received from all parts of the country. The experimental work has consisted in the construction of "object lesson" roads in various districts, to show how the work should be done. Some of these experiments have been conducted with the aid of "good-roads trains" operated conjointly by the railways, the manufacturers of road machinery and the engineers and general staff of the Road Enquiry Office.

The Hon. James Wilson, Secretary of Agriculture, also made an address on this subject, from which we take the following extracts:

We have established within the Department of Agriculture, at Washington, an office for the study of road material. We are calling upon young men who have graduated in engineering institutions to take practical work with us, so that we may be able to supply the demands coming from all parts of the country for men skilled in road making. Our laboratory is designed to assist each locality in determining the use of materials it may happen to possess. Few of our towns and cities have facilities for doing this work. Many of the failures in road building in the past are due to the use of materials unsuited to the conditions of climate and traffic.

The work of the Department of Agriculture along the line of road building is intended to be educational and experimental, as it is along other lines in which it is engaged. I am well satisfied that the condition of the public roads at he present time is a correct indication of the amount of educational work that has been done along the line of road building. If what the Department is endeavoring to do now with regard to helping to build object lesson roads (which has been done in half the states of the Union) and the study of road material for the information of the people had been done when our government was organized, the people would have understood how to build roads long before this time—would have understood the values of the materials in all parts of the United States. And I am well satisfied, also, that when the people are thoroughly informed in the several states and territories with regard to the science of road building there will be no hesitation in levying taxes to carry on the work.

Each section of our country has problems peculiar to itself, and to the end that all should have consideration the Department of Agriculture has a science agent in each of our great subdivisions, bringing them into touch with the laboratory at Washington.

Mr. J. B. Lloyd, Member of Congress from Missouri, thought that the "Office" should be raised to the importance of a Bureau of Roads, with enlarged appropriations and a larger staff of engineers to go through the country and investigate road conditions and materials. As to the claim that the Road Inquiries Office has devoted its attention mainly to stone roads, he pointed to its recent pamphlet on the construction and maintenance of dirt roads.

ARMY WORK ON THE PUBLIC ROADS.

Gen. Nelson A. Miles, U. S. A. (retired), spoke on the subject of government and military roads. He referred to the necessity of a good system of roads for the mobilization of troops. He advocated the employment of the army in road improvement. The mounted forces now represent 50% of the army, and he considers this too high, as in Europe it represents only some 5 to 10%. The plan which he had proposed to the War Department was to take 20% of the cavalry and organize an "advance corps" to undertake topographical and survey work, to study routes and roads, and to obtain long lines of good roads. He also advocated the employment of the army in road improvement work, instead of confining it to the monotony of camp life.

DIRT ROADS AND ROAD ORGANIZATION.

Mr. A. W. Campbell, Highway Commissioner and Engineer for Ontario (Canada), delivered one of the most interesting and practical addresses of the convention. The subject assigned to him was "The Science of Road Making," but he stated that until a better system of organization is adopted it is of little use to discuss the proper methods of constructing and maintaining roads, and when the system is adopted the carrying out of the methods must be entrusted to experts and not to unskilled men, as at present. At the present time the road supervisor is practically in entire charge of the work, with no superior officer, and there is no organization and no system of work. As they hold their positions for but a short time, each man is likely to undo the work done or begun by his predecessor in office. They mean well, but they are ignorant of the principles and practice of good road work, and their own road work is but a side issue. The result is that time, money and labor are wasted in absolutely ineffective work. Every year this work goes on, patching here and there, filling mudholes, etc., and still the roads are never any better. To spend more money under such a system would simply mean more waste and no permanent improvement.

The matter should be treated as a business and commercial proposition, and some plan and system of organization adopted for the proper construction and maintenance of roads, with a certain amount of money spent and work done each year. This should provide for not only the building of new hard roads but also the improvement of the present dirt roads. In Canada, the road movement at first met with unexpected opposition from the farmers, who resented it as an interference with their rights and an imputation upon their practice. They also thought it meant that they would be required to pay the cost of expensive stone roads, such as are built in Europe. This opposition has been overcome, especially as the movement is based on the principle that as everybody benefits in some way from the good roads, everybody should bear a share of the expense of obtaining them. This is effected in Canada and in Europe by the co-operation of the government, with a continuation of local, state and national aid.

There is no doubt that dirt roads can be made good roads, and this has been proved in Canada. In some communities the good dirt road is the best and most expensive that can be afforded, although in other communities a stone road costing $25,000 a mile may be the most suitable. It is impossible to lay down plans of construction that will be suitable for every class of road, and therefore one of the important points is the classification of the roads, and the classification of jurisdiction over them. In dirt road construction (and all road construction) in districts not absolutely arid, drainage is one of the essential principles. The foundation must be drained, the surface must be drained, and the ditches must be kept open so as to discharge the water quickly. The earth base carries the load, and if this is allowed to become wet is will be heaved and honeycombed by frost and made incapable of carrying the load of traffic. As traffic increases and the road becomes more important, the good dirt road may be improved by covering it with a bed of gravel, well rolled. Half the roads in this country will be dirt roads for the next 25 years, and farmers will be satisfied if good dirt roads are maintained. This can be done by proper drainage and the use of grading machines.

Mr. Campbell thought it as unreasonable to expect the farmers to pay all the cost of good roads because they use them to send their goods to market, as it would be to expect manufacturers to pay the cost because their goods are distributed by the roads. In Ontario, the provincial government, the county and the township each pay one-third of the cost. The labor-tax system is not to be blamed for present conditions; it was good in its day and has served its purpose well, but must now be replaced by some other system better adapted to modern conditions. The first thing in road improvement is not simply to get more money, as it would only be wasted under the present system. The first thing is to perfect local, township and county organization, and then to improve the existing roads, putting the work in charge of competent men under the supervision of expert engineers. Then it will be time to call for state and national aid.

BICYCLES AND AUTOMOBILES.

Mr. Otto Dorner, of Milwaukee, described the work done by the wheelmen's association a few years ago in forwarding the good road movement and in making the farmers realize that this would benefit them as well as the wheelmen. Mr. W. E. Scarrit, President of the Automobile Club, and Mr. A. A. Pope, the bicycle and automobile manufacturer declared that the automobile is to be the ally of the farmer in obtaining good roads. Mr. Scarrit thought that the automobiles will do

for the individual what the railways have done for the people at large. They will be standardized and cheapened until the farmers will use motor cars and motor wagons for business and pleasure, but the roads must be improved before this can be done. Mr. Pope stated that he founded the first instructorship in road construction at the Massachusetts Institute of Technology, and that all the universities are now educating men as road engineers. It is these men, and not the country farmers who know nothing about road construction, who should be employed to build and maintain the roads.

THE BROWNLOW-LATIMER ROAD BILL.

Hon. A. C. Latimer, Senator from South Carolina, said that this country inherited its system of road administration from that which obtained in Great Britain until 1836, when the British government took charge of the roads, and he pointed out that the roads are under government direction in every country which is cited as an example of good roads. The reason why matters have not been changed for the better here is that the people have not desired a change so strongly as to demand it. He thought that people are now beginning to demand a change. He proceeded to argue mainly on the basis of organizing to get money from the government rather than to perfect the system which controls the expenditure of the money. The general sentiment of the convention appeared to be that improvement should begin with local and county organization, to be followed by state and then by national aid. The Brownlow-Latimer bill contains the following provisions, besides one calling for an appropriation of $24,000,000, in three annual instalments of $8,000,000:

There shall be established in the Department of Agriculture a Bureau of Public Highways, composed of three commissioners. Two of these shall be appointed by the President, as follows: One from the political party in control of the executive branch of the government (who shall be the chairman), and one from the largest minority political party. Both shall have practical knowledge of road engineering and construction. The third member shall be detailed by the President, and shall be an officer of the Engineer Corps of the U. S. Army, of rank not lower than captain. Each commissioner is to receive a salary of $5,000 a year, that of the engineer officer to include his pay.

Half the expense of the improvement or construction of any public highway under this act shall be paid by the United States Treasury, and half by the state or territory or its civil subdivisions, the state having the right to distribute its portion of the cost among these subdivisions. To receive the benefits of this act, it must be shown that the highway to be built or improved is of public importance, that it will be maintained and kept in repair without the aid of the United States, and that the state has provided for its portion of the cost.

A PRACTICAL EXAMPLE.

Mr. Lane, of Huntsville, Ala., said that while the good roads question is in part a national matter it is largely a local matter also. If individual districts have not good roads it is often their own fault, and government aid would not help them. Madison county, Alabama, now has 250 miles of macadamized turnpike and gravel road. The movement was started 12 years ago, and a proposed issue of bonds, after being defeated at an October election (when roads were good), was passed at a January election (when the roads were almost impassable). The county issued $100,000 in 30-year 4% bonds, and built 60 miles of road, the result was that a second issue of $100,000 was made, and an engineer engaged to take charge of the work, contracts being let to local farmers. As a result of the engineering assistance about 120 miles of road were built. Of the present 250 miles, the maximum cost has been $4,800 per mile, and the minimum cost has been three miles for $1,050. In level country, $600 a mile for drainage, shaping and rolling will make a good road even in black earth. The county has recently spent $5,000 for road machinery with which to maintain its good roads, and one of the rural mail carriers has applied for permission to use an automobile. In the remarks which followed this address, it was shown that the constitutions of several states prohibit rendering aid to internal improvements.

Mr. Frank E. Nevins, of the U. S. Mail Service, described his experience in establishing rural mail delivery routes in the western states. Indiana has built several hundred miles of gravel and macadam roads. Arkansas has done good work under a state aid act which provides for a state engineer, but Illinois has nothing better than the old ineffective system of neighborhood assessment. The establishment of the rural delivery system has resulted in much improvement to the roads, but still the requirement that the carriers shall make trips of 25 miles a day is too severe in most cases, and men are continually resigning on account of the hard work. With good roads this mileage can be easily accomplished. He thought that the cost of road improvement should be distributed over every person and corporation by a general tax, and that no good road system will be obtained until the government takes up the matter.

Mr. David R. Francis, President of the Louisiana Purchase Exhibition, said that in 1889, when Governor of Missouri, he advocated the employment of convicts upon the public roads, but the idea was abandoned because the people thought it would be dangerous. One reason for the delay in completing the Exhibition is that not enough good roads were built for handling material and exhibits, although the engineers had urged their construction. With the continued wet weather and the clay soil it was consequently very difficult to haul the material. Mr. J. A. Holmes, State Geologist of North Carolina (and Chief of the Department of Mines and Metallurgy at the Exhibition), said that as a result of 20 years experience in the use of convicts for road work in North Carolina all objections to the system had gradually disappeared. The cost per man per day for maintenance is 30 cts. when employed on the road as against 40 cts. when kept in jail, while free white labor on the roads costs 75 cts. Escapes are relatively few, and there is not found to be any bad influence upon the convicts or the communities from having the men thus kept before the public. On the contrary, the influence upon the men is distinctly good, owing to the regular employment, in outdoor work, and they earn money in this way which is given to them when their term expires. If each county works its own convicts as a separate gang, requiring an overseer to every few men, the cost will be high, but the better plan is to combine the men into large gangs.

Mr. James Owen, M. Am. Soc. C. E., of Newark, N. J., said that New Jersey has been building roads for 25 years and has now over a thousand miles of hard roads. In each locality the local materials and conditions must be considered and engineering assistance employed if the best and most economical results are to be obtained. Without such expert advice there will be a waste of money, and one trouble is that so many people think it is a very simple matter to build roads and are ready to undertake the work.

The variation in the road laws of the different states was very clearly shown in the various speeches. In Alabama, counties can issue bonds for roads, but in Arkansas they cannot do this, and the constitutions of Michigan and other states prohibit the state from assisting internal improvements. Hon. John W. Folk, of St. Louis, described the road commissioner system of Missouri, and remarked that while plenty of money was spent, the commissioners do not know how to build roads, and so the money is practically wasted. He advocated a State Highway Commission, with engineering assistance. One of the interesting features of the convention was a roll call of states with a five-minute address from the representative of each delegation, while the remarks were somewhat colored by enthusiasm, they indicated, as a whole, that very general attention is being given to the matter, and that in many states earnest attempts are being made to devise some system of obtaining better roads. Addresses were also made by representatives from Great Britain and Canada, Sweden, Cuba and Brazil.

ROAD CONSTRUCTION AT THE EXHIBITION.

The "model street" at the St. Louis exhibition includes sample lengths of macadam, brick and asphalt paving, and the state of New Jersey has two samples of its standard stone road construction. The paved part of each road is 16 ft. wide, with an 8-ft. shoulder and a slope of ¾-in. to the foot from each side. This crowning is given to the subgrade, which is well rolled. The macadam road consists of 6 ins. of 2½-in. stone, rolled to 4 ins.; 3 ins. of 1½-in. stone, rolled to 2 ins.; and 1 in. of ¾-in. screenings. The two second layers are wetted during rolling. These exhibits are under the direction of Mr. R. A. Meeker, State Engineer of Highways, and they were visited by a large number of delegates at the convention.

PREVENTING THE GROWTH OF ALGAE IN WATER SUPPLIES.

Great public interest has been aroused during the past few weeks by the announcement in the daily papers that the Department of Agriculture at Washington had discovered a new method of treating public water supplies to prevent the growth of algae and of certain pathogenic bacteria.

We have refrained from publishing or commenting on the matter, believing it better to await the official publication regarding it than to place reliance on the premature reports in the newspapers. The full report of the Department has just been issued* and from it we reprint the following extracts, giving the facts of chief interest to engineers. We have commented on these discoveries in our editorial columns:

The necessity and importance of maintaining by every possible means the purity and wholesomeness of public water supplies have caused those in authority to welcome a method which would in any way serve as an additional safeguard against the pollution of reservoirs or would prevent the bad effects produced by the growth of algae and similar organisms.

While the best known cases of water pollution are those due to the presence of typhoid and other germs which have given rise to serious epidemics, there are a vastly greater number of water supplies which are rendered unfit for use, not because they are dangerous to public health, but on account of the very offensive odor and taste produced in them by plants other than bacteria. By the year 1878 there was on record a list of over 60 cities and towns in the United States which had had serious trouble because of the presence of certain forms of vegetation in their reservoirs, but since then thousands of water supplies throughout the country have been rendered unfit for use by this cause alone. Early in the year 1891 the special report upon the examination and purification of water by the Massachusetts State Board of Health was published; this being the most complete treatment of the subject which had appeared up to that time. This report has been supplemented by further investigations and experiments, and the work accomplished by this board in perfecting methods for insuring a pure water supply has established the standard both in this country and abroad for similar lines of investigation.

WIDE DISTRIBUTION OF TROUBLE CAUSED BY ALGAE IN WATER SUPPLIES.

In order to demonstrate the very wide distribution of the trouble caused by algae in water supplies throughout the United States, a circular letter was sent to about five hundred of the leading engineers and superintendents of water companies, asking for information in regard to the deleterious effects produced by plants other than bacteria in water supplies with which they were familiar. Many instructive replies were received, indicating that those in authority were extremely anxious to be provided with some efficient remedy for preventing the bad odors and tastes in drinking water, and that they considered the subject worthy of most careful investigation. Quotations from some of the letters received are given below:

CALIFORNIA.—Any efforts in the direction of preventing the growth of algae will be gratefully acknowledged. So long as the growth is healthy it is a benefit, but as soon as the algae break up then trouble begins.

COLORADO.—We have a reservoir of water that has recently become affected through the presence of micro-organisms of the algae type that impart to the water a disagreeable fishy odor and render its use objectionable.

ILLINOIS.—The water tasted and smelled like rotten wood.

Trouble serious enough to cause general complaint by consumers on account of odor and taste.

People declared that the water was musty. The appearance of the growth is yellowish-brown, and as nearly as I can describe it the smell is musty. I certainly think the subject worthy of the best thought and work the Government can give it.

INDIANA.—The growth increased to such an extent that we were compelled to cement the bottom and 5 ft. up the sides. It was as dense as a field of clover in June.

Taste was said by the people to be woody or fishy, like rotten wood or decayed fish. At one time the report got out that the body of a missing man had been found in the reservoir.

KENTUCKY.—Fishy odor and taste, rather musty.

The odor was so strong that we had to discontinue sprinkling the streets and lawns.

*Bulletin No. 64, Bureau of Plant Industry, Department of Agriculture, by Geo. T. Moore and Karl F. Kellerman.

Urgency in this case is great, indeed almost imperative, since the condition of the water during the past two or three summers has culminated in formal action by the authorities.

MASSACHUSETTS.—Trouble very serious; some years water is unfit to drink. Present year odor and taste are not so strong as last year, when it was almost impossible to drink it.

The odor was so bad that it would be almost impossible to take it as far as the mouth to taste it. Horses refused it at the street watering troughs and dogs fled from it.

NEW JERSEY.—Dark green gelatinous substance in water, causing a stench almost unbearable.

Have seen Uroglena so abundant that an odor could be plainly detected one-third of a mile away.

NEW YORK.—Strong fishy odor and taste; also odor of "smartweed." Popular complaint was dead fish in water mains.

Odor and taste were fishy, popularly attributed to dead fish; but this is absurd, as the odor is that of live fish.

Very rank, water smelled bad, particularly when warmed. Tasted bad, but not injurious to health. Looked better than tasted and smelled.

Water became unfit for use, musty or cucumber taste and smell, odor very strong in hot water; water became slimy, making it exceedingly hard to filter. Odor and taste at times decidedly fishy. A bright green powder seemed to have been sprinkled on surface.

I am much interested to know that you are taking up an investigation of algae and organisms. So many cases of trouble of this kind have come to my attention that any listing of them would be very difficult.

I am devoutly thankful that science in this particular instance has got beyond the pursuit of science for recreation's sake and is doing good and endeavoring again directly to be of much use to mankind. I believe your work is the first done in line of either cure or prevention from algae conducted in a rational manner, or so far as I know even attempted, and I have been connected with or well informed on public water supplies and their management all my professional life of some thirty-five years. The worst case I know of is at the —— reservoir. A special commission is at this moment charged with the duty of advising whether or not property worth some two million dollars is to be abandoned on account of annual trouble from algae.

OHIO.—Complaint from customers of a fishy taste in water like the slime from fresh-water fish.

Water had a fishy taste, causing a general kick; consumers laid it to the fish in the reservoir.

All water drawn from house bibbs had an objectionable and strong odor, the popular idea being that it was due to dead fish.

The towns A— and B— both have vile water, A— all the year round, B— for six or eight weeks in the hottest part of the summer. A—'s water has a vile odor, offensively musty. All vegetables, cereals, coffee, and such edibles and drinks made with the water are scarcely endurable to the visitor.

PENNSYLVANIA.—Water smelled and tasted as if dead fish were in it.

The water during the autumn is so foul in taste and odor that it was necessary to shut off the supply. The odor is similar to that of decayed fish.

The first season of using reservoir the water became so fishy that it was almost unfit for use. Since that, owing to our care of reservoir, we have had no trouble whatever.

TEXAS.—At this time of the year algae are fierce; some days we are on top and some days the algae are on top. Costs us an average of $25 a month for cleaning out algae from two reservoirs.

METHODS IN USE FOR PREVENTING BAD EFFECTS DUE TO ALGAE.

In order to prevent the odors and tastes above described, engineers and those in charge of water supplies have tried various remedies, none of which has been perfectly satisfactory. Since few of the algae can develop without sunlight, the most frequent recommendation has been to cover the reservoir, and this method has proved successful in a few instances. However, the expense involved is so great as to make the remedy prohibitive in most cases, and other methods have had to be resorted to. One precaution which is now almost universally recommended as a means of preventing the growth of algae is to remove all the organic matter possible from the reservoir and to keep the source of supply as free as can be from dead and decaying animal and vegetable matter. In one notable instance millions of dollars have been spent in the removal of earth and the substitution of gravel at the bottom of an immense new reservoir. It remains to be seen, however, whether this will be sufficient to insure permanent freedom from these troublesome plants.

It is certain that atempts of this kind will delay the appearance of algae in quantity, and, wherever it is possible to do so, every effort should be made not only to clean up the reservoir at the time of its construction, but to keep it as free as possible from organic matter after it is filled. In addition to cleanliness a direct pumping system with duplicate, in case of breakdown or repairs, has often been recommended for use with ground water, which usually produces a more luxuriant growth of algae and similar organisms than surface water. Where it has been necessary to store such water, it has been advisable to limit the capacity of the reservoir, and frequently this storage is only intended to be used in case of fire. Even so, the cleansing of the reservoir and the frequent flushing of the water mains has been considered necessary. In storing surface water subdividing the reservoir is occasionally resorted to, and means of obtaining frequent agitation are introduced wherever possible. The pumping of air into water or aerating it by means of a spraying apparatus is often of considerable value in removing foul gases which may be in solution, but the effect of aeration upon the growth of algae in a reservoir has been very much overestimated, in some cases the quantity being actually increased by this means.

The filtration of water, both mechanically and by sand, which has proved so effective for the removal of pathogenic bacteria has been recommended as a means of removing the odors and tastes caused by algae, but the results obtained have not given promise of success. Perhaps the most careful experiments to determine this point have been conducted by those in charge of the Ludlow reservoir at Springfield, Mass. Here the annual trouble from algae for the past fifteen years has been so great that every possible means has been used which offered any relief from the effects produced by these plants. On page 4 of the "Special Report on the Improvement of the Present Water Supply and an Alternative New, Independent Supply," made by the board of water commissioners to the city council of the city of Springfield, Mass., April 14, 1902, the following statement is made:

We find, as the results of the experiments of filtration, made with the sanction of your honorable body during the last fifteen months, that to purify the waters of this source by filtration would be not only doubtful as to the degree of purification, but so expensive in the cost of construction and perpetual maintenance thereafter as to make it inexpedient to attempt improvement by such a method. Your board has given constant and personal attention to the experimental work, and is convinced that the excessive growths of obnoxious fresh-water organisms, notably the Anabaena, impart to the reservoir such rank and persistent tastes and odors as to make uncertain entire removal by any method of filtration except that of the expensive kind, applicable only to the filtering of extremely small quantities of water, and requiring constant attention and adjustment.

The State board of health, in a special report (p. 84) submitted at the same time, say that the results of the experiments indicate, in the opinion of the board, that by double filtration it will be possible to purify the Ludlow reservoir; hence there seem to be differences of opinion as to the value of this treatment for the removal of odors and tastes, but on account of the expense involved there is not likely to be any very extensive use of this method.

DESIRABILITY OF OTHER METHODS.

While each of the above-mentioned methods has been used with some success, it is generally conceded by engineers that there is no known remedy which is universally applicable. It is the practice of some of the highest authorities to recommend that reservoirs frequently polluted by algae be abandoned, and steps taken to provide an entirely new system of supply. This is, of course, the last resort, as in all such cases a large loss of money is involved. One fact is certain. If any known method of preventing the growth of algae was considered truly effective, it would under all circumstances be recommended.

Because of the unsatisfactory results or the prohibitive expense of the present methods recommended for ridding reservoirs of algae, it seemed advisable that the problem be taken up from an entirely new standpoint, one that would take into consideration the biological aspect of the question and perhaps furnish a solution, through a study of the physiology of the organisms under laboratory conditions. A series of investigations were therefore undertaken to discover, if possible, some substance which, because of its extreme toxic effect upon the algae involved, would absolutely prevent their growth in water supplies.

DETERMINATION OF A PHYSIOLOGICAL METHOD.

In determining such a physiological method of dealing with reservoirs contaminated by algae, two conditions had to be considered: The remedy should not only be readily available and cheap enough for practical use in the largest reservoirs and by the poorest communities, but under the conditions used it must also be absolutely harmless to man; the maximum amount necessary to kill the algae being far below the amount which could in any way affect the consumer of the water. Of the large number of substances experimented with, few gave encouraging results. Free chlorine at a dilution of 1 to 10,000, and sulphur dioxide in saturated aqueous solution at 16° C., diluted 1 to 1,000 and to 10,000, will destroy many of the common forms of algae, but sulphur dioxide and chlorine are likewise very injurious to animal life. Silver has a very high toxicity, and were not the expense prohibitive, would undoubtedly warrant extended tests. Mercury and lead are, of course, out of the question, and zinc requires too high a concentration to be practically considered. The ordinary sodium, potassium, and ammonium salts are innocuous, as are most of the acids.

Reviewing the experiments carried on in the Laboratory of Plant Physiology, as well as the results obtained by other investigators, it seems that copper sulphate is the substance best adapted to the work in question. This salt has a very high toxicity for algae, and experiments with a number of the forms usually found in reservoirs, and the source of much trouble, have shown that inconceivably small amounts of copper are poisonous in a high degree. These experiments demonstrated, however, that all algae and protozoa are not equally sensitive. Among the latter Paramaecium is killed in three hours by a 1 to 1,000,000 solution, while Amoeba, Difflugia, and Spirostomum die within two hours. Crustacea are more resistant, some—Cypris and Daphnia especially—requiring as much as 1 part copper sulphate to 10,000 of water to kill them. Mosquito larvae die at a concentration varying from 10,000 to 200,000.

In the experiments conducted in this laboratory it has not been possible as yet to include all of the organisms known to pollute water supplies. It is believed, however, that, pending the completion of more extensive work, the data at hand will be of considerable benefit to those who have to deal with contaminated reservoirs. The method of procedure in studying this question was to determine roughly the death points of the forms under consideration, using Van Tieghem cells. Accurate solutions were then made, with distilled water, and 200 c. c. of each solution was pipetted into an Erlenmyer flask. The algae, if filamentous forms, were rinsed; if free-swimming, they were concentrated by the Sedgwick-Rafter* method from 500 to 5 cc. volume, and this 5 cc. was added to the treated water. The inaccuracy due to the addition of the 5 cc. of untreated water to the 200 cc. of treated water was disregarded. Whenever possible, a test of these concentrations, determined experimentally, was made under natural conditions by treating the pool from which the species under consideration was taken. If this was impracticable, an additional series was carried through in aquaria of 15 liters capacity, in which were kept goldfish, frogs, minnows, crustacea, and rotifers. Since in no case was there an appreciable difference in the effect of a concentration upon a particular organism under either natural or artificial conditions, no special record is made of these gross experiments.

We omit the tables giving the detail of the experiments, and in its place present the following table, giving the strength of copper sulphate solution apparently required to kill each of the several species tested.

Name of species.	Parts of water to 1 part of copper sulphate required to kill.	
Chlamydomonas Piriformis (Dill.)	2,000	
Raphidium Polymorphum (Fres.)	50,000 to	75,000
Desmidium Swartzii (Ag.)	100,000	
Stigeoclonium Tenue (Ag.) (Rabenh)	50,000 to	500,000
Draparnaldia Glomerata (Vauch.) (Ag.)	50,000 to	500,000
Navicula (Sp.)	200,000 to	300,000
Scenedesmus Quadricauda (Turp.) (Breb.)	300,000 to	400,000
Euglena Virdis (Ehrb.)	300,000 to	400,000
Spirogyra Stricta (E. Bot.) (Wille.)	75,000 to	100,000
Conferva Bombycinum (Ag.)	1,000,000	
Closterium Moniliferum (Bory) (Ehrb.)	1,000,000 to	2,000,000
Synura Uvella (Ehrb.)	1,000,000	
Anabaena Circinalis (Raben.)	3,000,000	
Anabaena Flos (Aquae Breb.)	3,000,000 to	5,000,000
Uroglena Americana (Calk.)	5,000,000 to	10,000,000

EFFECT OF COPPER ON ANIMAL LIFE.

The foregoing tables clearly demonstrate the effectiveness of copper sulphate as an agent for the destruction of algæ, and as the cost for an amount of this salt necessary to make the strongest solution required will not exceed from 50 to 60 cts. per million gallons, but one condition remains to be satisfied—that it shall be absolutely harmless to man, domestic animals, and fish under the conditions used.

In general, animal life is less susceptible to injury by copper than is plant life, though most of the higher plants, some of the fungi, and, as the preceding tables show, certain algæ will live in concentrations of copper sulphate that would be fatal in a few hours to fish and frogs. The critical concentration for game fish is higher than that for such fish as carp and catfish. Black bass in good condition have endured concentrations of 1 to 50,000 for many weeks with no apparent discomfort, while 1 to 100,000 was sufficient to kill German and mirror carp in a few hours, and 1 to 500,000 killed the most susceptible in a few days. Mud catfish are affected at practically the same concentration; goldfish at slightly greater, while yellow perch are perhaps less susceptible than goldfish. This agrees with the results of Perry and Adams,† who state that minnows and goldfish live indefinitely in a 1 to 200,000 solution.

Ever since copper compounds have come into general use as fungicides, the question as to their effect upon the human system has received more or less attention.‡ At times there have been vague and misleading statements in the public press, calculated to alarm those who are in the habit of using vegetables and fruits which have been subjected to treatment with Bordeaux mixture. The popular belief seems to be that copper is a poison, but it is found upon examination that the very best authorities are by no means agreed upon this point. It is true that after the question had been discussed for seven months before the Belgian Royal Academy of Medicine, in 1885, it was finally decided that copper compounds in foods were harmful, but it should be remembered that in the whole discussion, where every effort was made by one side to show that copper was an actual poison, not a single instance was given of injury to health resulting from the daily absorption of a small quantity of copper. On the other hand, many instances were cited where foods containing copper in considerable amounts were used without producing any harmful effect whatever. It should be noted also that the law prohibiting the use of copper in regreening fruits was repealed by the French authorities after the discussion before the Belgian Academy.

*Whipple, The Microscopy of Drinking Water, New York, 1899, p. 15.

†Perry & Adams, 4th Rept. River Polut. Conn. 2: 377-391.

‡Spraying Fruits for Insect Pests and Fungous Diseases, with a Special Consideration of the Subject in Its Relation to the Public Health. U. S. Department of Agriculture, Farmers' Bulletin No. 7, 1892. See also Bull. No. 6, Div. Veg. Path., U. S. Dept. Agric.

According to Thiemann-Gartner,[1] chronic copper poisoning has never been proved. The supposed copper colic was discussed by Burcq[2] before the Congrès Internationale d'Hygiène in 1878, and declared by him to have no existence; he even went so far as to assert an immunity against cholera for the workers in copper during various epidemics at Paris, Toulon, Marseilles, and elsewhere, but this statement he afterwards modified with reference to the epidemic of 1832. The good health of copper workers is also noted by Houlès and Pietra-Santa,[3] though they do not claim for them immunity from typhoid and cholera. Gautier[4] states that persons working in dye factories, where the hands, faces, and even hair were colored green by copper, were physically unaffected, which is true also of copper turners, who remain apparently in the best of health although constantly in an atmosphere highly charged with copper dust.

A considerable number of experiments have been made to determine the effect of copper upon man when taken into the intestinal tract. For fourteen months Galippe[5] and his family used food cooked and cooled in copper vessels, the amount of copper present in the food being sufficient to be easily determined. Kobert's experiments[6] show that a 60-kg. man can take 1 gram of copper per day with perfect safety. From his own results Lehmann[7] considers that copper to the amount of 0.1 gram in vegetables may produce bad taste, nausea, possibly colic and diarrhea, but nothing more serious. He has himself found peas containing as much as 630 mg. of copper per kilogram not distasteful, and 200 mg. consumed at a single meal was without effect. A very careful and thorough series of tests have shown that some individuals, at least, can take copper even to the amount of 400 to 500 mg. daily for weeks without detriment to their health.

Medicinal uses of copper compounds are cited by Du Moulin.[8] He has prescribed 12 to 15 cg. for scrofulous children, for cases of ophthalmia, etc., and found no ill effects. Copper sulphate in doses of 40 to 50 cg. for four or five days has proved beneficial to children with diphtheria.

Summarizing from a large number of experiments, Bernatzik[9] concludes, as follows: After entering the stomach only small quantities of copper are absorbed by the blood, and toxic action occurs only when the necessary amount can accumulate in the circulation. Silver, copper and zinc have almost the same medicinal properties, the difference being of degree rather than kind. They differ markedly from other heavy metals, having no harmful effects upon the tissues, and producing no fatal functional injuries; hence they are not poisons in the same sense as are lead, mercury, arsenic, antimony and phosphorus. Moreover, in the case of copper, after suspension of the dose the injured functions return to the normal.

It is evident that there is still a considerable difference of opinion among eminent authorities as to the exact amount of copper which may be injurious, but as a very conservative limit we may accept 0.02 gram as the amount that may with safety be absorbed daily. According to Merck's Index, the National Dispensatory, and the United States Dispensatory the dose of copper sulphate for tonic and astringent purposes is one-fourth grain, or 0.016 gram; as an emetic, a dose of five grains, or 0.33 gram. Thus it is seen that even if the maximum concentration of copper sulphate necessary to destroy algæ in reservoirs were maintained indefinitely, the total absorption from daily use would be very far below an amount that could produce the least unpleasant effect. Taking a dilution of one to one million, which in all cases would be sufficient to prevent the growth of a polluting algal form, it would be necessary to drink something over twenty quarts of water a day before an amount which is universally recognized as harmless would be introduced into the system, while more than fifty quarts would have to be consumed before there would be danger of producing an unpleasant or undesirable effect. As will be seen from the preceding tables, the use of copper sulphate at this maximum strength of one to one million would need to be resorted to only in extreme cases, and for a very short length of time, for, the reservoir once entirely free from the organisms, a very much weaker solution would be sufficient should any further application be necessary.

Perhaps the strongest argument in favor of using a chemical treatment of this kind is that even though enough copper should be added to a reservoir to make a one-millionth solution, nothing like this amount would appear in the water distributed. A very large percentage of the copper is combined with the algæ and precipitated in other ways, so that practically none would remain in solution after the first few hours.* Samples of water taken from a reservoir treated with sufficient copper sulphate to make a solution of one to one million, failed to show any reaction for copper after twenty-four hours, although all the algæ were killed. It is believed that the process used of evaporating down the original quantity and testing by the delicate potassium ferro-cyanide method would certainly have detected copper had it been present in the proportion of one to fifty million. Other tests were made by different chemists, but always with negative results.

In addition to the use of copper sulphate in reservoirs containing water to be used for domestic purposes, there are possibilities of its application in treating irrigation reservoirs, small pleasure lakes, fish ponds, oyster beds, etc. Here it may often be desirable to exceed the strength of solution that would represent the maximum required in a municipal water supply. This would be done not only to kill all the algæ, but to destroy or drive away reptiles and other pests, leaving the water perfectly clear and clean. The use of some such method for the destruction of mosquito larvæ also seems worthy of attention. The mere removal of the great mass of algal growths in stagnant pools undoubtedly reduces the number of larvæ by destroying this source of their food and depriving them of protection from fish and other enemies. This is probably the explanation of the reported* decrease in the number of mosquito larvæ after spraying a lily pond with Bordeaux mixture, although it is possible that the strength of the solution used may have been partly responsible for their death. It is believed that it will not be impracticable to use the amounts of copper sulphate necessary to actually destroy such larvæ. Certainly this method if effective offers considerable advantages over any now in use, and it should be thoroughly tested. Co-operative experiments are now under way with the Bureau of Entomology to determine the strength of solution necessary to kill larvæ of different species and ages under various conditions.

METHOD OF APPLYING THE COPPER SULPHATE.

The method of introducing the copper sulphate into a water supply is extremely simple. Though any plan will suffice which distributes the copper thoroughly, the one recommended and used by the Department of Agriculture is as follows: Place the required number of pounds of copper sulphate in a coarse bag—gunny-sack or some equally loose mesh—and, attaching this to the stern of a rowboat near the surface of the water, row slowly back and forth over the reservoir, on each trip keeping the boat within 10 to 20 ft. of the previous path. In this manner about 100 lbs. of copper sulphate can be distributed in one hour. By increasing the number of boats, and, in the case of very deep reservoirs, hanging two or three bags to each boat, the treatment of even a large reservoir may be accomplished in from four to six hours. It is necessary, of course, to reduce as much as possible the time required for applying the copper, so that for immense supplies with a capacity of several billion gallons it would probably be desirable to use a launch, carrying long projecting spars to which could be attached bags each containing several hundred pounds of copper sulphate.

In waters that have a comparatively high percentage of organic acid it is sometimes advisable to add a sufficient amount of lime or some alkali hydrate to percipitate the copper. The necessity for this will never occur in a limestone region, as in this case there will always be enough calcium hydrate or carbonate to cause the desired precipitation. The precipitation of copper does not mean the destruction of its toxicity, for experiments conducted in this laboratory have confirmed Rumm's† results that the insoluble salts of copper, such as the hydrate, carbonate, and phosphate, are toxic only if they are in contact with the cell, but are highly toxic in that case.

PRACTICAL TESTS OF THE METHOD.

WATER-CRESS BEDS.—The first practical test of the treatment of water for the purpose of killing out extensive growths of algæ was made in the fall of 1901 near Ben, Va., in connection with the cultivation of water cress for market. Water cress is grown there, as well as in other parts of the country, in large quantities during the winter, it being a valuable crop at that season of the year. The cress is confined in beds made by constructing dams across a small stream, which maintains a water level not too high for the growth of the plants and yet permits flooding when there is danger of a freeze. In the locality where the experiments were carried on the water was obtained from a thermal spring with a temperature the year round of about 70° F. Such a temperature was particularly favorable to the development of Spirogyra and similar filamentous algæ, so that when the cress was freshly cut they frequently increased to such an extent as to completely smother out a large part of the young and tender plants. The only known remedy under such conditions was to rake out the water cress and algæ and reset the entire bed. This was an expensive method, however, besides being successful only about half the time. Consequently, it was very desirable to devise some means of preventing the growth of the algæ without injuring the water cress, and the treatment by means of copper suggested itself. At first a strong solution of copper sulphate was used, spraying it on the algal covered surface of the beds, but this only destroyed the few filaments with which the copper came in contact, the large mass of algæ being practically unaffected. The method of applying the copper by means of dissolving it directly in the beds was next tried, and the success of the treatment was almost immediate evident. In this case the amount of copper added was about equal to a strength of 1 to 50,000,000 parts of water, but it is probable that by the time it reached most of the Spirogyra it was considerably weakened, as it was impossible to prevent a slight current of fresh water from passing through the beds at all times.

The success of the copper treatment for eradicating algæ from cress beds has been thoroughly demonstrated, and there is no reason why growers should have trouble from this cause in the future. The strength of the solution used for killing the algæ is so very much weaker than that which might affect the cress that there is no possible danger of injuring the latter if the solution is used by any one capable of observing ordinary care. The question of how long a treatment is effective must, of course, depend upon conditions, but it is believed that the application of the proper amount of copper once or twice a year will in most cases be sufficient to keep down any algal pest. The manager of the Virginia Cress Company writes, under date of April 12, 1904:

> The "moss" has given me no trouble at all this winter. In fact, I have for six months only had to resort to the copper sulphate once. . . . All the conditions were favorable last fall and early winter for a riot of "moss," but it did not appear at all until just a few days ago, and then yielded to treatment much more readily than it did when I first began to use the copper.

WATER RESERVOIRS.—The successful elimination of algæ from the cress beds of the South, under conditions which were particularly favorable to the growth of these pests, made it desirable that experiments be inaugurated calculated to demonstrate the possibility of ridding water reservoirs of the disagreeable odors and tastes caused by similar organisms. While it was realized that the popular prejudice against any chemical treatment of drinking water was strong, it was believed that the very weak solution, together with the very rapid disappearance of the salt added, would not render it a prohibitive method when applied under the direction of the proper authorities. It was also found that consumers of a water which possessed a disgusting odor and taste were not so prejudiced against the use of even a chemical method of extermination, provided it could be proved that no bodily harm would result.

In the spring of 1903 there was brought to the notice of the Department the supply of a water company in Kentucky, which promised to furnish a most satisfactory test. Ever since the construction of their reservoir it had given off an unpleasant odor. For the first two seasons this was supposed to be due to decaying vegetation, but later years demonstrated the well-known "pig-pen" odor due to algæ, and this increased from year to year until it was almost unbearable.

In July, 1903, when the trial was begun, the microscopical examination demonstrated an average of:

	Per c. c.
Anabæna	7,400
Clathrocystis	1,100
Eudorina	200

There were about 25,000,000 gallons of water in the reservoir at the time of the experiment, and on account of the great number of blue-green algæ present it was decided to apply the copper at a strength of 1 to 4,000,000. About 50 lbs. of copper sulphate was accordingly placed in a coarse sack and this, attached to a boat, was dragged over the surface of the reservoir, giving especial attention to the region which seemed to contain the greatest number of Anabæna filaments.

The decrease in the number of organisms as the result of this treatment during the next twenty-four hours was very decided. In two days the surface was clear and the water had lost its blue-green color, becoming brown, due to the dead organisms held in suspension. There was a slight increase in odor during the first two days after treatment, but this was followed by a gradual subsidence until it had entirely disappeared, not to appear again that season. The following list of counts made from surface examinations at one station illustrates what went on throughout the reservoir, and shows the almost immediate effect of a 1 to 4,000,000 solution of copper sulphate upon the number of filaments of Anabæna flos-aquæ. The treatment was made July 9:

	Filaments per cubic centimeter.
July 6	3,400
July 10	54
July 11	8
July 13	0
July 15	0
July 20	0

It remains to be seen what the condition will be during the coming summer, but it is believed it can never be any worse than at the time of treatment, and it is reasonable to suppose that there will be considerably fewer organisms this year than last. Even though an annual treatment of the reservoir prove necessary, involving a cost of from $25 to $50, the already great improvement in the quality of the water will certainly make it justifiable.

Other experiments of a similar character were carried on in different parts of the country with reservoirs of a

[1] Thiemann-Gartner, Handbuch und Beurtheilung der Untersuchung der Wasser, Braunschweig, 1895.
[2] Burcq. Congrès Internationale d'Hygiène. 1: 529, 1878.
[3] Houlès and Pietra-Santa, Journal de Pharmacie et Chimie, 5th Ser., 9: 393.
[4] Gautier, Le Cuivre et le Plomb, Paris. 183.
[5] Galippe, Compt. Rend., 84: 718.
[6] Kobert, Lehrbuch der Intoxicationen. (Original not consulted.)
[7] Lehmann, Münch. Med. Wochensch., 38: 603.
[8] Du Moulin, Journal de Pharmacie et Chimie, 13: 189.
[9] Bernatzik, Encyclop. d. ges. Medicin., 11: 429; Encyclop. d. ges. Heilkunde, 11: 429.

*Absorption, according to True and Ogilvie (Science, N. S., 19: 421), would materially reduce the quantity of copper in solution. See also Bull. No. 9, Veg. Phys. and Path., U. S. Dept. Agric.

*Hedrick, Gardening, 11: 295.
†Rumm, l. c.

capacity of from 10,000,000 to 600,000,000 gallons. While the results were all favorable, it is deemed best not to publish any detailed account until the effect of the treatment can be followed through another season. The summer of 1903 was cold and wet, and in some cases the decrease in the number of organisms may have been due to these factors. However, the several instances of the very sudden and rapid disappearance of forms which were present in tremendous quantity, without any reappearance, indicated that the treatment was most effective. Those in charge of these water supplies reported that they were well satisfied with the result.

EFFECT OF COPPER UPON PATHOGENIC BACTERIA.

TYPHOID.—The value of copper sulphate as an agent for the destruction of algæ polluting reservoirs suggests its use in cases where the organism is pathogenic. Since this salt is fatal to the algal growths, it seemed probable that it would also destroy bacteria, and that cholera germs and typhoid germs might succumb to its action.

The sterilization of public water supplies by chemical means has so far seemed an impossibility. Nearly every known substance has been tested, but the high concentrations required to produce the desired effect, the extreme toxicity of the agents, their cost, or the difficulty of application, have eliminated all but copper sulphate as a possibility for the present purpose.

The high percentage of copper sulphate given by most of the authorities who have investigated the use of copper sulphate as a germicide seems to preclude the idea of its practical use for the purpose desired. It should be remembered, however, that these investigators were working for a very different end, namely, to find concentrations destructive to bacteria in the presence of large quantities of albuminoid and fatty matter. Experiments conducted under similar circumstances have confirmed the above results, but the conditions obtaining in public water supplies are widely different. Here the amount of albuminoid matter is so small that the death point of the typhoid or cholera organism is lowered tremendously and very dilute solutions of copper are shown to be toxic. The tabulated results on the succeeding pages demonstrate this fact.

These tables [not reproduced.—Ed.] show that Bacillus typhi is more sensitive to copper sulphate than is coli, that the para group are about equally sensitive, and that temperature has a very important bearing on the toxicity of the copper in solution. At room temperature, which is near the temperature of a reservoir in summer, a dilution of 1 to 100,000 is fatal to typhi in three to five hours; at 5° it requires twenty-four hours for complete destruction.

ASIATIC CHOLERA.—The method of procedure in determining the toxic concentration for Microspira comma (Spirillum choleræ) was identical to that employed in the case of Bacillus typhi. The tests which were made show that the toxic limits of these two pathogenic organisms are very similar and that Microspira comma is slightly more sensitve to copper sulphate than is Bacillus typhi. To destroy the cholera germ requires about three hours in a 1 to 100,000 solution at a temperature above 20°. A longer exposure or a higher concentration is necessary to produce this result at lower temperatures.

It will be seen that the concentration of copper required is considerably greater than the maximum necessary for the destruction of algæ, and would, of course, be injurious to the aquatic animals normally present in a reservoir if it were allowed to act for any great length of time. Experiments in this laboratory have demonstrated, however, that the time necessary to remove Bacillus typhi is from three to four hours in summer, twenty-four hours in the coldest weather, and that under such conditions the solution does not injure fish and frogs or the common aquatic plants such as Elodea, Myriophyllum, and Lemna. To remove the copper at the desired time the method suggested in the preceding section in the case of acid and soft waters may be employed—that is, precipitate the copper by some soluble hydroxide or carbonate. This somewhat complicates the treatment, as it will be necessary to determine from the character of the water the amount of copper necessary to produce a solution of 1 to 100,000, as well as to estimate how much of the hydroxide or carbonate should be added. That such work be conducted under the constant and direct supervision of competent authorities is even more important than when treating for algal contamination.

COLLOIDAL SOLUTIONS.

The preceding experiments have dealt with copper in solution as the salt of some acid. The effect upon water of metallic copper surfaces, producing the so-called colloidal solution of copper, deserves especial mention. As Nägeli, Galeotti, and Israel and Klingman have abundantly demonstrated, the slight amounts of copper thus brought into solution are highly toxic to many form of algæ and bacteria.

The experiments carried on in this laboratory show that it is undoubtedly possible to exterminate Uroglena and some forms of Spirogyra by suspending in the water copper foil sufficient to give an area of about 1 sq. cm. to each 100 cc. of water. This would not be a practicable method of treating a reservoir, but it suggests the possibility of sheet copper being used as a preventive of pollution. By suspending large sheets of this metal at the intake of a reservoir, it is probable that conditions would be rendered sufficiently antagonistic to algal growth to maintain the sterility of a reservoir after it had once been thoroughly cleansed of polluting forms. It would, of course, be necessary to keep such copper sheets clean in order to prevent a reduction of the toxic action due to the formation of an insoluble or slimy coating on its surface. It is possible that some electrical method may be perfected for rapidly obtaining a strong colloidal solution, which will furnish a more convenient means of application than that of the crude salt.

In regard to the bacteria causing cholera and typhoid, the importance of the specific toxic effect of colloidal copper is probably much greater than with algæ. The following tables [not reproduced.—Ed] show the proportions of the area of copper to the quantity of water and to the time and the temperature necessary to produce the complete sterilization of water containing these pathogenic germs.

(The tables show, in brief, that with water containing 1 sq. cm. of copper foil to 5 cu. cm. of water, bacillus typhi colonies were reduced from 2,241 at the end of ½ hour to 24 at the end of 12 hours. A test with an amount of copper four times as great caused complete sterilization at the end of 8 hours. Bacillus coli proved slightly more resistant to the action of copper. The cholera bacillus was killed more easily than the typhoid bacillus.—Ed.)

It is evident that the amount of surface exposed in any ordinary copper tank would far exceed the amount demanded for the above results, and it is likewise certain that after standing from 6 to 8 hours at room temperature in a clean copper vessel water becomes safe to drink even though it may have contained cholera and typhoid germs. It remains to be seen whether or not the application of these facts to conditions in the Tropics, where cholera is abundant, will be of any value. It would seem that the construction of canteens and other water vessels from copper might serve as an additional safeguard, if not an actual preventive of this disease, and would prove of considerable value where distillation or efficient filtration apparatus is not at hand.

CONCLUSIONS.

It is believed that the foregoing experiments demonstrate the possibility of the use of copper sulphate for the destruction or prevention of growths of algæ in water supplies, and that when used under the direction of a competent authority, it is the only practicable remedy for this trouble capable of universal application which has ever been proposed. It is, of course, probable that with the experience which must come from a wider opportunity for testing this salt, many improvements will be made in the practical application of the treatment to large bodies of water. However, it is hoped that the results already obtained, together with trials now under way, will make it possible to begin using this method within a short time upon a large scale throughout the country.

NECESSITY OF KNOWLEDGE OF ORGANISM AND CONDITION OF RESERVOIR.—It cannot be too strongly emphasized, however, that harmless as the method undoubtedly is under proper control, it must always require a certain amount of definite knowledge in regard to the condition of the reservoir before any treatment can be made, even by those thoroughly able to conduct such an experiment. This is regarded as a fortunate requisite, since it will tend to prevent the irresponsible or careless dosing of reservoirs by incompetents, who are occasionally in charge of water supplies.

Before the amount of copper to be added can possibly be known, it is absolutely necessary to ascertain the exact character of the organism causing the trouble. This will make a microscopical examination of the first importance. Also, the sooner such an examination reveals the presence of the polluting form, the more effective will be the treatment. If examinations are made at short intervals during the entire year, it is possible to detect the troublesome forms at their first appearance and by prompt treatment to destroy the algæ before the consumer is aware of any difficulty. The early detection of the algæ will also make a considerable difference in the expense of the treatment, as it may require fifteen or twenty times as much copper to clean a reservoir after the bad odor and taste are evident than it would could the application have been made before the organism began to rapidly multiply. In all cases the use of copper as a preventive rather than a cure is advocated, and this cannot be intelligently applied unless the microscopical examinations are thorough and frequent at the time of year the trouble is to be anticipated.

On account of the necessity of determining the nature of the organism and the time of its appearance as nearly as possible, it will become as imperative for water companies to employ some one competent to make these examinations as it now is to have a chemist or bacteriologist. In fact, in regions where the difficulty from algæ is great, the microscopical examination must take precedence of everything else as a means of keeping the water palatable and satisfactory to the consumer.

In addition to the character of the organisms and the earliest possible determination of their appearance, it has already been pointed out that the chemical constitution, the temperature, and other special conditions of the water are factors in determining the line of treatment. No specific instructions are given in this bulletin for the amount of copper sulphate which is to be used for each species of algæ which is known to affect water supplies, because it is impossible to make a definite statement without a knowledge of the conditions already mentioned. Each reservoir must be regarded as an individual case, requiring special knowledge and a particular prescription. It is believed that the public water supplies of this country are worthy of such special care, and it would be a matter of regret if the method proposed here should ever be regarded as a universal panacea to be used by every one, regardless of the organism to be eradicated and the condition of the water.

APPLICATION OF METHOD FOR DESTRUCTION OF PATHOGENIC BACTERIA NOT DESIGNED TO REPLACE EFFICIENT MEANS OF FILTRATION ALREADY IN USE.—The use of copper sulphate in clearing polluted reservoirs of pathogenic bacteria, such as typhoid and cholera, is regarded as incidental to the main purpose of the investigation. There already exists a most efficient means of preventing the appearance of these organisms in water supplies, and under no circumstances can it be considered that the method as described is expected to replace or supersede slow sand or any other efficient filtration. There are conditions, however, which sometimes make it desirable to thoroughly sterilize a reservoir, and under those circumstances the use of copper sulphate is believed to offer a new and adequate way of dealing with the difficulty. Experience has demonstrated the impossibility of compelling consumers of what may be an infected water to boil it, or observe other precautionary measures, and the absence of proper filtration plants in a very great number of cities and towns in this country makes it necessary that some efficient method for destroying disease germs in water be employed until the danger from pollution be past. Up to this time no satisfactory and yet harmless method has been known that would become effective in the course of a very few hours and the cost of which was in the reach of every community. It is believed that the results of the experiments upon typhoid and cholera germs described in this bulletin indicate that it will be possible under competent direction to employ copper sulphate with perfect safety in any municipal water reservoir which may have become infected with some non-spore-forming disease germ. Its application to barnyard tanks and pools as a preventive of hog cholera may also prove to be of value. Since the selective toxicity of this salt renders it fatal to pathogenic forms peculiar to water, while the common sapropuytic or beneficial bacteria are unaffected, the method is particularly well adapted for this purpose.

MEDICINAL USE.—While it is not within the province of this bulletin to discuss or recommend any line of medical treatment, reference should be made to the fact that certain eminent practitioners, after reviewing the results here published are of the opinion that the use of copper in cases of typhoid fever and related diseases should be more thoroughly investigated than it has been heretofore. It was the testimony of several that other intestinal troubles, more recently presumed to be due to the presence of certain disease germs in drinking water and milk, had responded most favorably to copper in one form or another.

FOUR-CYLINDER BALANCED COMPOUND LOCOMOTIVES; PARIS & ORLEANS RY. (FRANCE).

The French four-cylinder balanced compound locomotive of the De Glehn type for the Pennsylvania R. R. was described and illustrated in our issue of March 31, and it was stated that the engine is practically identical with some built for the Paris & Orleans Ry. We are indebted to Mr. Alfred De Glehn, Director of the Societe Alsacienne de Constructions Mecaniques, for a complete list of dimensions of a set of eight Atlantic (4-4-2) engines on this system, built in 1903 for the Paris & Orleans Ry., which are similar to other engines for the Paris, Lyons & Mediterranean Ry. The principal difference between these engines and the one for the Pennsylvania R. R. is that the former have six-wheel tenders (with the two rear axles placed close together and the springs connected by equalizers), while the latter has a tender mounted on a pair of trucks and is fitted with a water scoop for taking water from track tanks.

The list of dimensions is given below in our standard form:

Dimensions of Atlantic (4-4-2) Four-Cylinder Locomotive: Paris & Orleans Ry. (France).

RUNNING GEAR:	
Driving wheels (4)	6 ft. 8 ins.
Truck wheels (4)	3 " 9¼ "
Trailing wheels (2)	5 " 0 "
Tender wheels (6)	4 " 1 "
Driving wheel centers	Forged iron
Truck and tender wheels	Steel tired

Driving wheel tires secured	By retaining rings
Engine truck	Swing center
Journals, driving axles	8 9-32 x 9 1-16 ins.
WHEELBASE:	
Driving, 7 ft. 0⅝ ins.; truck	7 ft. 6 9-16 ins.
Total engine	28 " 6½ "
Tender	14 " 9 "
Engine and tender	53 " 5 "
Truck pin to first driv. axle	9 " 6 "
Wheels having blind tires	None
Length of engine	38 ft. 8 ins.
Length of engine and tender, over all	63 " 0 "
Width, extreme	9 " 9 "
WEIGHT IN WORKING ORDER:	
On driving wheels	79,500 lbs.
On truck wheels	46,500 "
On trailing wheels	35,200 "
Engine, total	161,200 "
Tender, empty, 41,800 lbs.; loaded	98,000 "
Water in boiler and fuel on grate	14,300 "
Counterbalance: M. M. Assoc. rules	No
Piston rod, h.p., 85 lbs.; l.p.	120 lbs.
Main rod, h.p., 278 lbs.; l.p.	425 "
Crosshead, 238 lbs.; side rod	326 "
CYLINDERS:	
Size, h.p., 14 3-16 x 25 3-16 ins.; l.p.	25⅝ x 25 3-16 ins.
Ratio of area of h.p. to l.p piston	1 to 2.78
Crosshead and guides	Alligator, two-bar
Connecting rod, c. to c.	7 ft. 0⅝ ins.
Side rod, strap ends; length	7 " 0⅝ "
VALVE GEAR:	Walschaert.
Ports, exhaust, h.p., 14¼ x 3⅛ ins.; l.p.	20½ x 3⅛ ins.
Ports, steam h.p., 14¼ x 1⅝ ins.; l.p.	20½ x 2 1-16 ins.
Bridges, width, h.p., ⅞-in.; l.p.	1 1-32 ins.
Eccentrics, throw, h. p., 7 15-32 ins.; l.p.	9 1-16 ins.

FOUR-CYLINDER BALANCED COMPOUND LOCOMOTIVE ON THE DE GLEHN SYSTEM; PARIS & ORLEANS RY., FRANCE.

Mr. Alfred De Glehn, Designer. Societe Alsacienne des Constructions Mecaniques, Belfort, France, Builders.

SLIDE VALVES:	Flat, semi-balanced.
Max. travel, h.p., 5⅛ ins.; l.p.	5⅛ ins.
Lap, neg. inside, h. p., ⅛-in.; l.p.	3-16 "
Lap, outside, h.p., 1 1-16 in.; l.p.	1 1-16 "
Lead, constant (full backward and forward gear) h.p., 5-16-in.; l.p.	9-32-in.
BOILER:	Straight top.
Barrel, diam. inside smallest ring	5 ft. 5⅝ ins.
Barrel plates, ⅝-in.; smokebox tube plate	1 in.
Horizontal seams	Butt joints, double riveted
Circumferential seams	Lap joints
Rail to center line	8 ft. 10 15-16 ins.
Length of smokebox	5 " 11 "
Smokebox arrangement, M. M. Assoc rules	No
Injectors (2)	Friedmann restarting
Working steam pressure	228 lbs.
FIREBOX:	Belpaire.
Length, inside, 10 ft. 4 ins.; width, inside	4 ft. 0½ ins.
Depth at front, 6 ft. 11 ins.; at back	4 " 9⅝ "
Crown, side and back plates	⅝-in.
Tube plate	1 5-16 "
Crown stays	Vertical, hollow
Firebrick arch	Yes
Stayboits, manganese bronze (hollow), drain	1 in.
Water spaces, front, back and sides	3⅝ ins.
TUBES:	
Thickness, 0.1-in.; pitch	3½ ins.
Diameter, outside	2¾ "
Length over tube plates	14 ft. 5¼ "
Area of tube openings	4.59 sq. ft
HEATING SURFACE AND GRATE AREA:	
Heating surface, tubes (including ribs of Serve tubes)	2,402.9 sq. ft.
Heating surface, firebox	174.1 " "
Heating surface, total	2,577.0 " "
Grate area	33.4 " "
MISCELLANEOUS:	
Exhaust nozzle, single; drain	Variable
Exhaust nozzle, above cen. line of boiler	7 ins.
Smokestack, diameter, base, 20¼ ins.; top	17¾ "
Height above smokebox	2 ft. 8⅞ "
Height above rail	14 " 3½ "
Capacity of tender tank	44,000 lbs.
Capacity of coal space	12,100 "
Brake equipment: Westinghouse-European; quick-acting and high-speed.	

WATER SOFTENING.*

By James O. Handy.†

I.—Introduction.

Hard water owes its soap-destroying and boiler-incrusting properties to the compounds of lime and magnesia which it contains. These compounds have been dissolved by the water as it passed through fissures in limestone. In a sandstone or granite country the water is soft.

While discomfort and inconvenience result from the use of hard water in the household, the greatest trouble, expense and danger come from the use of hard water in steam boilers. In a coal producing district, steam users have to contend also with the corrosive effects of acid waters, from the mines and washers. Many well waters contain corrosive substances such as free carbonic acid and certain magnesia salts.

The troubles caused by acid waters are in most cases more acute than those produced by scale-forming ones, because in the former case there is actual destruction of parts of the boiler itself. Boiler incrustation is also a very serious matter. The danger of explosion through sudden access of water to overheated surfaces is always present. The waste of fuel is enormous, as the scale is a more or less perfect insulator, according to its composition and density.

The bill for boiler cleaning and repairs is extremely heavy when a hard water has to be used. These facts are in general well known, but they have not received the attention they deserve.

The railroad companies have been the greatest sufferers and their officials have been most active in investigating and applying relief wherever possible. The Railway Master Mechanics' Association has had committees working on the matter ever since 1873. They found that in some hard water districts, the flues in locomotives had a record as low as 18,000 miles, and lasted only seven months. Fire-boxes were used up in fifteen months to three years. In districts where soft water was available, flues made as high as 300,000 miles, and lasted as long as eight years. Fire-boxes 13 years old showed no signs of weakness.

The use of hard water in locomotive boilers meant not only heavy expense in renewals of wornout parts, but such loss of service from engines undergoing repair as to mean a crippling of the road. The fuel consumption of locomotives with freshly cleaned boilers was found to be far less for the same work than was the case with engines having scale-covered tubes. Impelled by considerations such as these, the railway men advocated most thorough search for soft water supplies. In cases where only hard water could be had, purification by chemical treatment was recommended as a means of relief.

It was soon recognized that the cheapest and most efficient chemicals for water softening were lime and soda ash. It was only natural that attempts should first be made to secure the benefits of chemical treatment by simply pumping the solution into the water flowing to the storage tanks or even to introduce chemicals into the water in the locomotive tenders. Both of these methods when skilfully managed, gave some degree of satisfaction and economy. It was evident, however, that neither the storage tank nor the locomotive boiler was the proper place to purify the water. It should be softened and clarified before it entered the wayside tanks.

Crude, two-tank purifying systems have been succeeded by compact machines which continuously soften, clarify, and deliver the water into the service tanks. Of about 100 softening plants in use on railways, over three-fourths are of the continuous type.

In the following sketch of the growth and present state of the art of water softening, I have endeavored to place the credit for successive improvements with those who appear to have been the first to suggest or apply them. The machines or systems now available for water softening purposes are carefully compared, with the idea of showing what is novel and valuable in each plan.

The author hopes that his endeavor to treat the subject impartially has been successful. If, however, injustice has been done inadvertently, he will gladly make amends.

II.—The Art of Water Softening.

Cavendish* discovered in 1766 that the addition of lime water to certain natural waters caused the deposition of carbonates of lime and magnesia to take place.

Thomas Henry† in the latter part of the same century proposed to soften hard water by the use of slaked lime or hydrate of lime.

Dr. Thomas Clark, of Aberdeen, in 1841 patented a method for making use on a large scale of the lime process for water softening. For determining the amount of lime required, he used the alkalinity test, and for ascertaining whether enough lime had been added the silver nitrate test was applied to the treated water. These tests are in use to-day. Clark also is credited with suggesting the use of a standard soap solution to determine the total hardness of waters, their soap-destroying power being quite an exact index to the total amount of lime and magnesia which they contain.

While very perfect chemically, Clark's water-softening process was carried out very crudely when regarded from an engineering standpoint. Masonry tanks set in the ground served for making limewater, for softening, and also for clarification. The time allowed for softening was from twelve to twenty-four hours, and the cost for treatment was unnecessarily high. Furthermore, the process had its limitations. It could only be used with perfect success on hard waters, in which the carbonates of lime and magnesia were the principal impurities present. Sulphates, chlorides or nitrates of lime or magnesia, while capable of destroying soap and causing many of the troubles due to hard water could not be removed by Clark's process.

Later on, in conjunction with Porter, the method of handling these more complex hard waters was taken up with some success.

In Germany, F. Schulze* in 1876, suggested the use of lime and soda for softening waters containing both bicarbonates and sulphates.

THE PORTER-CLARK PROCESS.†

There is not much data available as to the extent to which this process was put into actual use. The system consisted in the treatment of water by means of a solution of lime or soda, or a mixture of the two. The chemical solution was usually forced into the mixing tank by the pressure of the air expelled from a metal receiver by the incoming water. When the reservoir tank was full, the water was allowed to pass away through a filter press.

The system was ingenious but very expensive to install and operate. It must have required constant attention. If the slightest air leak occurred, the chemical feed was no longer in the proper proportion. With so little settling capacity the cleaning of filter presses must have required constant attention, especially with magnesian waters. The L. & N. W. Ry. Co.‡ softening by this process 7,000 gallons per hour at Camden Town. The hardness was reduced from 18° to 4° while the water was under 60 lbs. pressure.

The work of certain French and German inventors followed and improved on the processes of Porter and Clark. The engineers of the French railway "La Compagnie du Chemins de fer du Nord," installed their first softening plant in 1861. It differed from the Clark system only in the use of milk of lime instead of lime water. Large masonry reservoirs were used. No labor-saving appliances or means for exactly controlling the treatment were employed.

Their later type of softening plant consists of elevated steel tanks with means for mixing the chemicals and floating draw-off pipes for removing the softened water. Filters are used to effect final clarification.

It soon became evident to the engineers working in the water-softening field that the elements of heavy expense were labor and interest on investment in great reservoirs, etc., necessary for the carrying out of the intermittent process of purification.

The Clark process required, according to Rideal ("Water and Its Purification") two 40,000 gallon tanks for lime water and three 300,000 gallon settling tanks for a daily output of 250,000 imperial gallons. This meant a tank capacity of nearly 1,000,000 gallons in order to secure an hourly output of 10,400 gallons. A modern softening plant with a tank capacity of 240,000 gallons, softens 60,000 gallons of water hourly and is, therefore, 24 times as efficient as the Clark system.

There was great incentive to devise a simpler system of softening. If the operation of softening could be made continuous, the gain would be great. It seemed necessary simply to have a uniform chemical feed, a thorough mixing of chemicals with the water, and sufficient time for chemical reaction and proper sedimentation. Easy as this appeared, it has taken many years to satisfy all of these requirements.

CONTINUOUS SOFTENING PLANTS.

Berenger and Stingl were, we believe, the first to construct continuous softening plants. They were only moderately successful, but they were pioneers in the field. Their first apparatus‖ consisted of a reagent tank, in which the chemical solution was prepared by hand, and then continuously mixed with the hard water flowing to a mixing tank. Here the mixture passed down through a central pipe, striking a conical obstruction on the bottom. This deflected the stream side-ways over the entire cross section of the tank and its velocity was suddenly diminished, allowing some sediment to deposit. The clarification, and probably the chemical reaction also, were very imperfect. Filters were used, but they were soon stopped up, and proved very difficult to clean.

*A paper read before the Engineers' Society of Western Pennsylvania.
†Chief Chemist, Pittsburgh Testing Laboratory, Ltd., Pittsburgh, Pa.

*Fischer: Chem. Tech. des Wassers, 1880, p. 262.
†Archbutt: The Softening of Water, Eng. News, Dec. 22, 1898.

*Fischer: Chem. Tech. des Wassers, p. 267.
†Delhotel: L'epuration des Eaux, p. 309.
‡Rideal: Water and Its Purification, p. 219.
‖Delhotel: p. 308.

By enlarging and changing their apparatus Berenger and Stingl tried to overcome their difficulties. They were working on the idea that change of the direction of flow was the most important influence in assisting the clarification of the turbid mixture produced by adding chemicals to hard water. They next used a series of settling tanks* or "decanters," each one being of larger section than the one preceding, and each one having a sludge cock at the bottom. The incoming mixture passed by a pipe to a point just inside the opening of an inverted cone supported on the bottom of the tank. The cone was of such shape and size that it reversed the flow of water and threw it outward. This had the effect of diminishing velocity and allowing sludge to settle to some extent from the sides of the stream, past the cone, and down to the point of draw-off.

This plan effected much more perfect clarification than before, but it was still necessary to filter the water, and results were otherwise imperfect, showing that the conditions governing continuous and perfect softening had not been fully apprehended.

Pichler and Sedlaeck† followed with an apparatus evidently designed to meet the objection which had been made to the numerous tanks required in Berenger and Stingl's system. They made a machine consisting of concentric cylinders, the water passing up and down in annular spaces of increasing area, and finally out through an annular filter into a circular collecting canal. The sediment collected in the cone-shaped spaces terminating each cylinder.

The use of an annular filter and circular collecting trough seems to have originated with these inventors and represented a distinct advance in the art of water softening. The rest of the apparatus, while apparently simple, was actually complex, being costly to construct and difficult to operate. The sludge had to be drawn from all the compartments through a perforated pipe by one cock, and naturally the draught was very uneven. These inventors were also impressed with the idea that change in direction of flow was an important thing.

Gaillet and Huet,‡ after the experience gained in constructing Berenger & Stingl's apparatus, devised several improvements and constructed machines of their own. They built a high tank, filled with 45° shelves of V-shaped section. These were fastened alternately to opposite sides of the tower, so that the water to be clarified, when introduced at the bottom, rose by passing back and forth through these angular passage ways.

The settling influences on which the inventors depended were the growth of the particles by accretion, the loss of velocity by changes of direction and the friction and molecular attraction of the walls of the V-shaped troughs. Sludge, settling out and sliding down these inclined troughs was drawn off by cocks outside the apparatus. The nearly clarified water passed through a filter occupying the entire cross-section of the upper part of the softener.

Chemical reagent tanks furnished a proportional supply of a solution of the necessary chemicals. The later machines were cylindrical and contained apron-shaped inclined shelves which were arranged around a central sludge pipe. The sludge dropping on these shelves slid down undisturbed to the point of draw-off.

These inventors added much to the art of water softening. They seem to have been the first to make lime water continuously instead of intermittently. The chief criticism which can be made of their machine is complex construction and too rapid flow of water for the best results.

According to Delhotel§ Howatson's apparatus§ for water softening followed Gaillet's in point of time. In one form it consisted of two rectangular cone-bottom tanks, the water to be clarified flowing down the first and up the second. The upper half of the latter contained a series of slightly inclined partitions. Directly above these was a filter, and the purified water flowed away at the top.

These inclined partitions assisted the clarification by giving the precipitate a chance to become agglomerated into heavier flakes and to slide down the plates and settle into the cones below. The device was less perfect than Gaillet's.

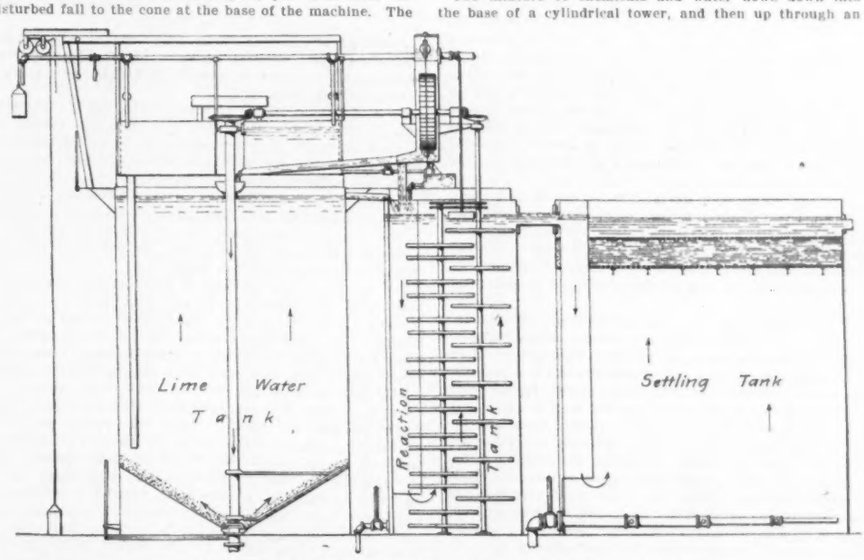
Dervaux** and Reisert have been building softening machines in Germany for over ten years. Their apparatus has many different forms. The lime saturator however, is always "cone" or "vase" shaped, an apparent improvement, but one which later experience has shown not to be necessary. Their arrangements for feeding chemical solutions are as follows: The hard water flows into a tank at the top of the machine. On the side of this tank, near the floor and at the same level, are two openings, the flow from which is controlled by micrometer valves. One valve connects with a pipe leading to the bottom of the lime water tank, and the other allows the passage to the base of the reaction tank of the water to be softened. Saturated limewater flows from the top of the limewater tank in amount exactly proportional to the feed of hard water to the base of the tank. The stock solution of soda ash is fed to a small box in which a float valve maintains a constant level. The soda ash solution is fed through a siphon connected by a chain with a float in the hard water box.

The mixture of the chemicals with the hard water takes place either in a box near the top of the machine, as in most of the European plants or else the solutions are carried separately down and into the side of the machine as in some of the American installations. The first plan is in a general way correct. The last is bad design, for only most imperfect mixing can take place without stirrers, when such a column of water overlies the point of entry.

The Reisert-Dervaux softeners have a novel feature in the submerged sand filter, which is arranged to wash itself automatically when clogged. This is a good feature, but it has drawbacks due not only to irregular action, but to the fact that hard water replaces soft in and above the filter during washing, and the output of the machine is therefore not all softened. The resistance of sand is high, and the amount of material required to clog the filter is less than is the case with excelsior filters.

Very few successful plants of this type are in use in the United States, up to the present time.

Desrumeaux,* a French inventor, seems to have been the first to utilize by means of a water wheel, the power of the water flowing into his softening machine. He used the power for driving a stirrer in his lime water tank. In both lime water tank and reaction tank he had annular, spiral passage ways for the rising water, thus giving it a steady though circuitous upward movement, instead of, as in Gaillet's machine, a zigzag one. Sludge, settling on the spiral plates, slide to outlets properly placed to favor undisturbed fall to the cone at the base of the machine. The feed for chemicals was controlled by valves operated by floats in the hard water box.



WATER-SOFTENING PLANT AT MIDDLEPOINT, OHIO.
The Industrial Water Co., Builders.

Desrumeaux's apparatus was introduced into this country several years ago by the Industrial Water Co., of New York. The machines now being put out by this company do not contain the spiral settling device. The size of the lime water tank has been increased, and an intermediate agitating tank has been added, so that Desrumeaux's idea, except the water-wheel, seems to have disappeared.

The method of operating the Industrial machine can be seen from the accompanying cut. This represents the arrangement at a railroad plant† at Middlepoint, Ohio, on the Pennsylvania Lines West of Pittsburg, Northwest System.

The large lime water tank and the spiral agitating tank are the characteristic features of the Industrial plants. The designers use three comparatively shallow tanks, erected on trestle work, in order to deliver softened water into a railroad supply tank. This has some disadvantages, in that it requires considerable ground space, a large and quite complex foundation, and the protection of exposed pipes from freezing.

The method of hoisting lime and soda to the top of the apparatus, by filling one bucket with water until it overbalances the weight of chemicals in the other, doubtless works all right; but the disposition of the water afterward must result in waste or inconvenience.

The flat-bottomed settling tank, with perforated draw-off pipes, will require quite frequent cleaning out, because magnesian sludge will not flow well to sludge holes.

Arrangements for ensuring an even upward rise in the settling tank seem to be wanting. The filter has some steadying influence, but hardly enough to guarantee perfectly even displacement of the water in the tank by the incoming water.

Analyses made by the writer and statements made by customers indicate that the Industrial machines soften water satisfactorily in the cases which were investigated. The criticisms, therefore, pertain mainly to engineering features, which would have a bearing on the cost of attendance and maintenance, as well as uniformity of working under varied conditions.

BRUUN-LOWENER SYSTEM.

In June, 1897, U. S. Patent 583,786 was issued to Julius Bruun for a "feed water purifier" (previously patented in Denmark in 1893). The essential feature of Bruun's system is the use of a two-compartment oscillating bucket as a means of proportioning the feed of chemicals to water. The chemical solution is kept in a semi-cylindrical vessel directly over the tipping-bucket. The hard water supply flows into the bucket continuously. As soon as one compartment is filled the bucket tips and discharges, and the other compartment fills. The movement of the bucket is made to operate a stopper-valve in the bottom of the chemical supply tank. This valve is so adjusted that it allows the required amount of chemical solution to pass before it closes again, being assisted in so doing by a weight and spring. The chemicals, cream of lime and soda ash solution, are kept in intimate mixture by means of a stirrer, which is also actuated by the motion of the tipping-bucket.

The mixture of chemicals and water flows down into the base of a cylindrical tower, and then up through an excelsior filter. The only mixing is the momentary one, occurring during the filling and emptying of the bucket and there is no provision made to ensure steady upward rize of water. On the contrary, the irregular feed would tend to produce eddies.

The Southampton municipal softening plant, installed in 1888, was one of the first continuous softening plants of large size, and is still the largest in the world. It was a great improvement on the Porter-Clark process. It is described elsewhere in this paper. The apparently new things in water softening introduced at this plant were: (1) The use of soft water for lime water. (2) The use of cloth filters, working efficiently at low pressure.

The municipal softening plant at Winnipeg is also a continuous plant and is, therefore, mentioned in this connection. Some new features found in this plant are: (1) A lime cream pump, continuously supplying lime water tanks. (2) A simple weir box and gage. (3) Special filter presses of large capacity. (4) Efficient carbonating box of special design.

These two plants work on very different waters, which require quite different treatment.

The Kennicott water softening machines represent the latest developments in continuous machines, and will be described later on. Their use dates from 1900.

The oscillating bucket is not a new device in the field of chemical manufacture, but its application to water softening is suggested in Bruun's and in Gaillet's patents, the former having adopted it as an essential feature of his apparatus.

Bruun's patent claims are for use of the tipping-bucket as a means of operating a feed valve in the chemical supply tank. Subsequent users of the bucket device have caused its motion to actuate feed-pumps (Davidson), or to lift and discharge chemical solution by spoon devices. (Kennicott, U. S. Pat. 732,357.)

*Delhotel: 327.
†Delhotel: p. 329.
‡Delhotel: pp. 331, 345, 348.
§U. S. Pat. 568,600, 1896; Pat. in France in 1893.
§Delhotel: p. 323.
**U. S. Patent 495,313, 1893. Also Delhotel: p. 325.

*U. S. Pat. 513,686, 1894. See also Dehotel's "L'epuration des Eaux."

†Water Softening Plant, Pennsylvania Co. R. R. Gazette, Oct. 2, 1903.

Archbutt and Deeley's contributions to the chemistry and mechanics of water softening may be appreciated by a study of their U. S. Patent 521,522 issued in 1894, and also an article on "The Softening of Water by the Archbutt-Deeley Process," by Leonard Archbutt, in Engineering News, of Dec. 22, 1898, a paper read originally before the Institution of Mechanical Engineers (Great Britain).

These inventors did not believe in continuous softening machines. They preferred to work with rectangular tanks, adding the chemicals and agitating with air forced in by a steam blower, through perforated pipes lying on the bottom of the tank. They noted and laid particular stress on the influence of this sludge in hastening the softening, and also the clarification, of the water. This is one of the most important points in water softening, but it had been noticed before (Fischer, Chem. Tech. des Wassers 1880, p. 268). The presence of crystals of carbonate of lime in suspension hastens the separation of carbonate of lime from solution by furnishing nuclei for the deposition of new crystals.

As regards the influence on speed of softening, these inventors claim that, under the most favorable conditions, four tanks, aggregating 108,000 gallons capacity, will turn out 45,000 gallons per hour. This is about twice the output which is expected from continuous plants of up-to-date design for the same tank area. The usual allowance by Archbutt and Deeley was apparently 1.4 gallons of tank capacity for each gallon of hourly output, which means for filling, agitating, settling and drawing off, only one hour and twenty minutes, which is rarely enough.

The practice in water softening in this country is to allow four hours for sedimentation after stirring up sludge and water together. Archbutt and Deeley introduced the practice of carbonating softened water in order to remove all tendency to after-reaction. They observed that water softened by their process formed deposits in condensers, injectors, etc., and that treatment with carbonic acid in small amount wholly stopped the trouble. They burned coke and injected the combustion gases directly into the draw-off pipe. The softened water in flowing down the pipe passed over baffles, causing it to splash up into the gas and dissolve some of it.

This method of applying the gas by means of a steam blower, and apparently without washing or cooling, cannot be efficient. Experiments by the author, giving four times the length of contact under similar but even more favorable conditions, failed to effect complete carbonating. It was necessary to change the method of exposure entirely.

In 1896 Goldsmith* took out U. S. Patent 558,018, and started to build water softening plants, operating under what he called the We Fu Go system. This system differs in no essentials from Archbutt and Deeley's plan, except that a steam engine is used to drive a paddle for agitating the water with the chemicals, instead of a steam blower injecting air for the same purpose. Neither device is original or patentable. The claims in Goldsmith's patent are for combinations of devices for feeding chemicals, and for stirring and drawing off the softened water. These methods were not adhered to in his later practice, nor were patentable devices substituted therefor. The softened water is filtered through a sand filter, embodying no features especially different from the usual gravity filter.

The results obtained by the use of We Fu Go plants have been excellent, so far as we know. The conditions for proper softening are very perfectly fulfilled. If the treatment is based on a correct chemical analysis, it is sure to be successful.

The system may be justly criticised on the following grounds:

(1) The system is intermittent. The feed and draw-off must be changed alternately from one tank to the other. Numerous valves have to be opened and closed.

(2) Frequent weighing out of chemicals and preparation of solutions is necessary.

(3) The tanks occupy much floor space.

(4) Unless raised on trestle work to give a gravity supply, all the water has to be pumped twice. Even if the total lift were no greater in the latter case, it would be a drawback, and an extra expense.

(5) Outside power is required for running paddles in treating tank, rakes in filter tanks and the hoist for lifting the chemicals.

The "Ideal" system of water softening, used by the Pittsburgh Filter Mfg. Co.,† is in most respects similar to the Archbutt-Deeley process. It is intermittent. Air is used for agitation, but it is furnished by a small pump instead of a steam blower. The chemical solutions are prepared at ground level and pumped to the treating tanks, thus saving the necessity for a hoist, and making it unnecessary for the attendant to go frequently up on the tanks. As in the We Fu Go system, sand filters complete the clarification of the water. These are of gravity or pressure type, as occasion may require.

Both of the companies just mentioned make plants especially for treating hot water, the chemical solution being pumped into the feed line, and then passing successively through a mixing tank and a sand filter into the boiler. Filters are in duplicate, so that one can be cut out for cleaning when necessary. In neither case is the general plan original. The Solvay Process Co., at Syracuse, N. Y., have purified and filtered their boiler water in essentially the same way for many years.

Stillman has taken out patents 595,793 (1897) and 656,311 (1900). These devices are for use in connection with railway water stations, and have been tried on the Southern Pacific Railway. The novelties in Stillman's plan consist in the use of compressed air for running a mechanical stirrer in his chemical tank, and also for forcing the solution into the water main. After entering the main, the mixture is made to flow through circulating tanks containing baffles. Thence it passes into the railroad service tank, which is used as a settling reservoir. The water then has to be drawn off through floating discharge pipes, and the sludge through appropriate drains. In the later patent, a water motor takes the place of the air-motor.

In criticising Stillman's method it may be said that it is an advance over the old method of sucking the chemical feed in through the service pump, in that it provides means for keeping the chemical solution stirred, and for mixing it afterward more perfectly with the water. The use of the railroad tank as a part of the softening apparatus seems to us poor economy, except as a temporary makeshift. The removal of sludge from a flat-bottomed tank must of necessity be unsatisfactory. The passage of water and chemical solution through a chamber with baffles is old in water-softening practice. Compressed air for regulating chemical feed was first used in the Porter-Clark process.* Later on the same people used a water motor for actuating chemical feed pumps.†

Published analyses (Railway Age, June 21, 1899, page 13), show that Stillman obtained satisfactory results. While possibly cheaper to install, the method, as a whole, cannot be recommended.

G. M. Davidson (U. S. patents 712,770, 712,771, 715,031 and 729,121, taken out in 1902 and 1903) has devised a method of water softening which is in use at several points on the Chicago & Northwestern Ry. He feeds his chemicals proportionately and continuously into the water by means of an adaptation of the tipping-bucket device. As the bucket tips back and forth it operates a stirrer in the chemical supply tank, and at the same time actuates two feed pumps which deliver the chemical solution in fixed proportions into the bucket.

The use of a tipping-bucket is not new, but the pump attachment is believed to be so. The Bruun-Lowener softener,‡ used in Denmark and to some extent in this country, has a tipping-oucket, the chemical solution being fed in from an overhead supply, through a stopper valve raised by a cam each time the bucket tips, and seated again by a spring.

Davidson, after filling a tank with water to which the proper amounts of chemicals have been added, agitates further by pumping water from the upper part of the tank and forcing it in at the bottom through a perforated pipe lying in the sludge. By this means a thorough contact with sludge with its attendant benefits is obtained. The time allowed for filling, settling and emptying is 12 hours. The standard plan has two 30 ft. tanks, 16 ft. high. These deliver, if necessary, 240,000 gallons in 24 hours. The tank capacity is about 154,000 gallons for an hourly output of 10,000 gallons.

In criticising the Davidson plant it may be said:

(1) That the appliances are well suited for perfect softening of the water. Results are chemically satisfactory, and good results are obtained from the use of the water in locomotive boilers.

(2) The plant is simpler and probably is less expensive to install than some of the machines on the market.

(3) In the matter of operation, however, the arrangement for drawing off the excess sludge seems imperfect. Magnesian sludge clings persistently to flat-bottomed tanks.

(4) The output for a given tank area is very low indeed.

(5) The ground space and housing required are very considerable.

For further particulars see "The C. & N. W. Ry. Co.'s Method of Purifying Water for Locomotive Boilers," G. M. Davidson, "Proceedings Western Railway Club," Feb. 17, 1903. See also "Railway and Engineering Review," Oct. 31, 1903, p. 783, for statement of cost of operating Davidson plants in July. The figures vary from 0.73 ct. to 6 cts. per 1,000 gallons, interest and depreciation not included.

THE KENNICOTT SYSTEM OF CONTINUOUS WATER SOFTENING.

This system is described in U. S. patents 646,108, 665,606, 703,596, 706,717, 717,215, and 732,357. March 27, 1900, to June 30, 1903. It is very extensively used in the United States, particularly in the railroad field. It is, however, of general application. Railroad requirements are more severe than any, except possibly municipal.‖

The general plan of working is very simple, the feed of chemicals and all the necessary stirring being automatic. The turning on of the water starts everything in operation and shutting it off stops it. The hard water enters a box near the top of the apparatus and flows out through a slot in the bottom to a water wheel. (The slot is made of the proper size to discharge the maximum quantity of water which is to be treated.) The water wheel operates a stirrer in the lime water tank, and also a lift wheel for raising soft water to the lime water measuring box. It has been found economical to use soft water for making lime water, and by means of this lift-wheel soft water is raised with very little power, indeed, to the point of use.

Soda ash, enough for 6, 12 or 24 hours, is dissolved in a tank, and is fed by a pipe controlled by a ball-float valve to a measuring box on a level with the lime water feed box. A float in the hard water box is connected by chains with swivel-joint lift pipes in the feed boxes.

As the level of the water over the slot in the hard water box rises and falls, the lift pipes, which have openings in their upper ends proportional to the size of the slot in the hard water box, rise and fall also. The length of each chain is so adjusted that the head of water over all three slots is always the same. The sizes of the slots in the lift pipes are made adjustable by screw caps. It is thus a simple matter to change the proportions of chemicals to hard water at any time.

The soft water delivered to the lime water feed box passes through the slotted lift pipe, which connects with a pipe passing to the bottom of the central lime water tank. Here it passes up through the excess of lime cream, and is changed into saturated lime water, which, flowing upward, meets the mixture of hard water and soda solution which have come together at the point of discharge below the water wheel.

A very thorough stirring takes place at this point, and the mixture flows upward and passes over the rim of the mixing cylinder. It then starts down the annular conical space outside the lime water tank. In this cone the velocity of the water constantly decreases, and the sediment produced by softening the water gradually settles away from the descending current. Arriving at a point just above the sludge cone, the water turns upward again, passing through baffle plates and depositing nearly all of the rest of the suspended matter. It finally flows through a wood-fiber filter and passes over into the service tank.

These machines are so designed that they deliver water into elevated service tanks without repumping. They require only one foundation, and the parts are well protected from freezing.

Tests by the writer prove that the conditions favoring uniform and complete softening are well taken care of in the Kennicott machine. The degree of softening is as high as with any machine, and the results are uniform when reasonable care is taken. The amount of labor actually necessary for operation is less than with any other machine with which we are familiar.

In criticism of the Kennicott machine it may be said that the feed of lime water is discontinued when sludge is blown out. The water level above the filter falls slightly, and the lift wheel cannot reach soft water until it rises again. This defect, which has apparently not interfered with general success, will doubtless be remedied. (Note: New device remedies trouble.)

The novel and valuable features of the Kennicott machines are: (1) The proportional feeding device for chemicals. The slotted lift pipes are simple and easily adjustable. (2) The mixing arrangements inside the main tank. The industrial mixer is a separate tank. (3) The conical down-take pipe, giving a descending water column of decreasing velocity, out of which the precipitate settles easily. Other machines have only a narrow cylindrical down-take pipe, or none at all. The base of the down-take cone is made of such area that there is no sudden increase of velocity when the current turns up again, but only a steady increase in the size of the passage all the way to the top. (4) The baffle plates not only steady the upward rise but assist in the final clarification and completion of softening in a way not always appreciated.

SUMMARY.

The essential principles of water softening which any successful machine must meet, are as follows:

(1) The scheme for feeding chemicals in the continuous system must be very precise at all times, and capable of easy adjustment when necessary. The devices must be as simple as is consistent with precision.

(2) The chemicals and water must be very thoroughly mixed, and for a sufficient length of time under proper conditions, so that the softening is sure to be completed in the time allowed.

(3) In the case of a continuous softening machine, its internal construction should be such that the steady progress of water through the machine is certain. There must be no eddies. If the supply is delivered intermittently or the rate of pumping is variable, it is absolutely essential that the uneven flow be counteracted. There is a tendency toward short cuts in any case which the apparatus should be designed to meet.

(4) The apparatus should be so designed that clarification will be very complete, leaving an insignificant amount

*A description of a plant on this system at the Lorain Steel Company's blast furnaces was given in a paper by Mr. Goldsmith in Engineering News of May 17, 1900.

†A plant built by the Pittsburgh Filter Mfg. Co. for the Tennessee Coal, Iron & Railway Co., at Ensley, Ala., was described in Engineering News of July 2, 1903.

*Delhotel.

†Rideal: "Water and Its Purification," 1897, p. 219.

‡U. S. Pat. 583,786, June, 1897, Feed Water Purifier, Julius Bruun.

‖The Kennicott system was described in Engineering News of May 15, 1902.

of work for the filters. This reduces the trouble and expense of operation.

(5) The time allowed for the completion of the chemical reaction must be sufficient. The apparatus, if continuous in operation, should hold four times the maximum hourly output required. If intermittent, the time for filling and emptying tanks must be added to the four hours standing. This makes the tank area in the intermittent system usually about twice that in the continuous system.

(6) The softened water should be perfectly clarified when discharged.

(7) Labor and superintendence must be cut down to a minimum.

Judged by such of these standards as apply to intermittent systems, the We Fu Go, Ideal, Stillman, and Davidson systems are properly designed to secure satisfactory softened water. They vary from each other in the amount of labor required to operate, the Davidson being apparently the simplest of the intermittent plants.

All intermittent plants except possibly the Archbutt and Deeley,* require from two to four times as much tank capacity as the continuous machines for the same output.

The Industrial and the Kennicott machines are the only two continuous types which can be approved of when critically examined, and the measure of approval is less in the former than in the latter case, for reasons already enumerated.

INTERMITTENT VS. CONTINUOUS WATER SOFTENING PLANTS.

(1) CHARACTER OF WORK DONE.—Comparing results on waters of similar character we find good work by both types.

	No. 1.		No. 2.		No. 3.	
	Lime.	Magnesia.	Lime.	Magnesia.	Lime.	Magnesia.
Hard water..	0.80	5.62	7.40	2.46	23.75	4.60
Softened water	0.55	2.39	1.85	1.23	1.69	3.80
	No. 4.		No. 5.		No. 6.	
	Lime.	Magnesia.	Lime.	Magnesia.	Lime.	Magnesia.
Hard water..	19.46	6.60	27.8	8.54	24.04	10.10
Softened water	1.42	1.22	2.17	0.72	2.56	.88

Results show parts per 100,000.

Nos. 1 and 4 are Kennicott plants (continuous).

Nos. 2 and 3 are Pittsburg Filter Mfg. Co. plants (intermittent).

Nos. 5 and 6 are, respectively, Davidson and Stillman plants (intermittent).

The fairest test of the work of a softening plant is not the original hardness of the water, but the amount of lime and magnesia left in the water. Water of only moderate hardness is often more difficult to treat than a very hard one.

The lime is reduced to a smaller figure by the Kennicott plants, while the magnesia is brought a little lower by some of the others.

All of the results are good. The author made analyses 1, 2, and 3. The chemist of the Union Pacific Ry. made No. 4. No. 5 and No. 6 were by Mr. G. M. Davidson. (The original figures were stated in grains of calcium carbonate, etc.)

(2) COMPARATIVE OUTPUT OF PLANTS.—We Fu Go (intermittent); Lorain plant.—Four 100,000-gallon tanks = 400,000 gallons, produce 50,000 gallons per hour. Hourly output = one-eighth of tank capacity. Ground space for plant = 3,230 sq. ft.

Kennicott (continuous), McKees Rocks.—Capacity of softener = 257,000 gallons (gross). Hourly output = 60,000 gallons. Hourly output = one-fourth of tank content. Ground space = 850 sq. ft.

It will be noted that while the first plant mentioned above occupied about four times the area used by the other, and had twice the tank capacity on the same basis, yet its output was just half. The ratios of tank capacity to hourly output of several plants are:

Clark process (original intermittent)	20:1
We Fu Go (modern intermittent)	8:1
Kennicott (modern continuous)	4:1

The output of the Kennicott plant is seven times that of the Clark system, and twice that of the We Fu Go per unit of tank capacity.

(3) LABOR IN OPERATION.—1,200,000-gallon We Fu Go Plant, Lorain, Ohio.—Man required to run engine and look after shafting, belting, etc.: 24 large valves to be opened and closed daily at proper time. Two filters to clean. Sludge excess to be removed from four tanks. Twelve batches of chemicals to be weighed out.

1,440,000-gallon Kennicott Plant, McKees Rocks, Pa.—Boy to weigh out and prepare batch of chemicals every six hours. No engine or shafting. One valve opened to remove sludge four times a day. Dumping sludge lowers water and cleans filter.

(4) POWER FOR OPERATION.—We Fu Go Lorain Plant.—Engine required to run stirrers in four 30-ft. tanks and rakes in two 16-ft. filters. Plant depends on steam power for its operation.

Kennicott, McKees Rocks Plant.—All stirring or lifting required is done by the power of the water falling 8 ft. The power required is very small, as only one narrow blade stirrer is used. The use of the water for power makes the plant independent. When water is pumped to the plant everything starts.

(5) DURABILITY AND MAINTENANCE.—In most cases the intermittent plants are of wooden construction while the continuous ones are of steel. The depreciation of steel tanks will be next to nothing, because the alkaline solutions have a protective influence. This is not true of wood.

(6) CHEMICAL REGULATION.—The work of the intermittent plants when not located at places having a chemist is only checked up by imperfect chemical tests, (red color with phenolphtalein and color with silver nitrate).

Parties installing continuous plants, train operative to make simple but more enlightening tests (hardness, alkalinity, etc.).

SUMMARY.

Continuous and intermittent softening plants properly designed and conscientiously cared for, give first-class results. In order to get these results by the intermittent system it requires a larger plant, more labor and more power. Intelligent supervision is required for both kinds of softeners.

The continuous system has the advantages of simplicity and compactness, and is cheaper to operate, because it requires less power and less labor. The maintenance charges are less, if, as is usual, steel construction is used. Having few valves (one-fourth as many as in the intermittent system), there is little to get out of order.

EXTENT OF WATER SOFTENING OPERATIONS AND BENEFITS DERIVED.

There are in the United States and Canada to-day, about 275 water softening plants, with an aggregate capacity of approximately 65,000,000 gallons per day. Of these plants over 100 are in railroad service. The rest are distributed as follows:

	Plants.
Iron or steel works	35
Ice factories	16
Electric lighting companies	6
Street railways	4
Paper manufacturers	9
Laundries	6
Woolen mills	2
Glass companies	2
Cement manufacturers	3

Other users include:

Gas works,	Powder works,
Water-works,	Coal mining companies,
Municipalities,	Sugar refineries,
Hospitals,	Breweries,
Hotels,	Smelting works.

The extent to which water softening has already been carried in this country is in itself convincing proof that it pays well. Further proof may be found in a few concrete cases:

(1) The Chicago, Milwaukee & St. Paul Ry., by the use of soda ash, saved $75,000 per annum on boiler repairs.

(2) The Union Pacific Ry. Co., by the use of tri-sodium phosphate on one division for six months, obtained the following results: (a) Increased engine mileage 42.5%. (b) Washing out, decreased 60%. (c) Boiler work, decreased 65%. (d) Flues in better condition than ever before. The expense of treatment was too great and machines using lime and soda ash have replaced the phosphate plan.

(3) The Nichols Chemical Co. of New York, by the use of a continuous water softening machine obtained the following benefits: (a) Fuel saving of 20%. (b) Labor saving of 25%. (c) Boiler repair saving of 75%. For a 2,500 HP. plant, labor and chemicals cost only $2.40 per day. The water is no harder than Monongahela river water, before treatment.

(4) The Consumer's Co., Chicago, ice manufacturers, (Mr. J. T. Cole, Manager), installed a water softening machine and estimate the benefits derived as follows, on the basis of the same output:

Annual coal bill before softening water, 22,000 tons, at $1.35	$29,700.00	
Cost of removing scale from boilers	780.00	
		$30,480.00
Annual coal bill when softening water, 18,333 tons, at $1.35	$24,749.55	
Cost of removing scale	0.00	
Chemicals for softening	255.00	
Six per cent. interest on cost of plant	294.00	
		$25,298.55
Saving due to softening		$5,181.45

This exceeded the first cost of the plant, which, therefore, paid for itself in a year. The water used was from Lake Michigan, and is not harder than Monongahela River water.

III.—The Chemistry of Water Softening.

Before taking up the question of water softening, it is necessary to have a correct analysis of the water which it is desired to improve. A prominent superintendent of motive power of a well known railroad, recently told us that of six chemists working on parts of same sample of water only three agreed within reasonable limits. We presume that the differences arose chiefly from methods of combining the acid and basic radicals found.

In June, 1899, we analyzed waters from the Chicago & Alton Ry. Co.'s wells at Bloomington and Joliet, Ill., and give for comparison, the results turned in by another chemist on the same waters.

Parts per 100,000.

	Bloomington.		Joliet.	
	P. T. L.	Ht.	P. T. L.	Ht.
Carbonate of lime	29.15	3.06	28.29	3.30
Carbonate of magnesia	3.47	16.32	3.44	24.96
Sulphate of lime	1.65	19.75	7.58	42.70
Sulphate of magnesia	16.36	...	34.71	...
Sulphate of soda	...	...	1.12	...
Chloride of soda	3.14	2.93	14.85	13.99
Carbonate of soda	1.97	5.60	1.06	6.73

The samples were not taken at exactly the same time, but evidently we were working on substantially the same waters. The salt determinations indicate that. Otherwise we differed widely. We based our allotment of acids to bases on the behavior of the constituents after evaporation to dryness. Lime which remained insoluble in hot water certainly was not present as sulphate, chloride, or nitrate. As the magnesia, after evaporation to dryness, went mainly into solution in hot water, it could not have been present in the water as carbonate.

There is a theory that all the sulphuric anhydride found in water should be combined with lime if enough is present, and if not, give it all it will take. The other chemist seems to have worked on that plan.

This theory is advanced by Leffman. ("Examination of Water," p. 112.) He says:

> Since it is known that, at the high temperatures ordinarily reached in boilers, definite chemical changes occur, it is safest to exhibit the maximum amount of corrosive and scale forming ingredients which the water, under these circumstances could develop. Thus as calcium sulphate is practically insoluble in water above 212° F. (?), the proportion of calcium sulphate may be regarded as such as would be formed by the total quantity of calcium or the total quantity of sulphuric acid, according to which is present in the larger amount. Similarly, as the decomposition of magnesium chloride is induced by the high temperature of the boiler, the analytic statement should indicate the maximum proportion of this compound obtainable from the magnesium and chlorine present. These rules cannot apply absolutely to waters rich in alkali carbonates, since these would neutralize any acid formed from magnesium chloride, or even prevent its formation, and would prevent to a large extent the formation of calcium sulphate. Much remains to be determined concerning the effects of high temperature and concentration to which boiler waters are subjected.

This was in 1895. We do not know whether Mr. Leffman hold to the same views now concerning the best method of expressing results of analysis. Certainly no accurate calculation for water softening purposes could be based on results expressed by his method.

On the basis of our analyses, we figure lime and magnesia compounds in Winnipeg water as shown in the first column.

	Parts per 100,000. P. T. L.	U. of M.
Carbonate of lime	20.29	7.0
Carbonate of magnesia	11.30	23.7
Sulphate of lime	0.60	21.6
Sulphate of magnesia	17.25	...

A chemist at the University of Manitoba insists, however, on figuring it as shown in the second column, in spite of the fact that almost all of the lime comes down as insoluble carbonate on evaporating to dryness.

These instances will serve to illustrate the need of thorough discussion, and agreement on a uniform method of obtaining and expressing the analytical results on which water softening calculations are based.

*Archbutt and Deeley by drawing off without filtration in an hour or less, make carbonating necessary and materially limit the degree of softening.

ANALYSES OF TYPICAL WATERS.

Parts per 100,000.

	1	2	3	4	5	6	7	8	9	10	11
Silica	0.24	1.55	.83	0.60	...	.56	...	2.45	2.90	...	...
Carbonate of lime	0.89	1.92	2.52	6.90	6.16	2.68	...	42.05	23.20	5.27	2.59
Carbonate of magnesia	0.14	1.90	.92	3.23	1.73	.46	...	2.03	12.17	.46	1.64
Sulphate of lime	2.19	1.30	.39	.58	...	3.40	11.66	10.72	...	1.19	...
Sulphate of magnesia	...	...	...	.85	...	.45	4.83	22.98	...	...	...
Chloride of lime	.20	...	...	...	...	...	...	...	...	12.29	...
Chloride of magnesia	.58	...	...	...	2.19	1.25	...	...	...	5.19	...
Chloride of soda	...	.07	.80	...	1.52	2.47	1.82	2.86	.15	30.18	5.86
Sulphate of soda	...	.94	...	...	5.84	...	1.03	9.62	1.15	...	22.74
Free sulphuric acid	...	...	...	...	...	...	0.98	...	...	...	...
Nitrate of soda	...	...	...	...	...	...	...	...	...	...	3.15

Nos. 1 to 3 are good waters, giving no trouble in boilers.

Nos. 4 to 7 are fair waters, which, however, it pays to soften.

Nos. 8 to 9 are poor waters, the use of which, in locomotive boilers, makes new fire boxes necessary in two years.

Nos. 10 and 11 are waters which foam in locomotive boilers.

No.

1. Youghiogheny River water from point above Connellsville.
2. Grand Rapids, Wis., well water analyzed by G. M. Davidson.
3. Wellington, Mich., same analyst as No. 2.
4. Lake Michigan water, Chicago, Ill.
5. Nichols Chemical Co.'s supply, Long Island.
6. Allegheny River water, furnished to Pittsburg, October 8, 1903.
7. Monongahela River water at Rankin, Sept. 9, 1903.
8. Well at Council Bluffs, Iowa, G. M. Davidson, analyst.
9. Well at Boone, Iowa; ibid.
10. Water supply at Beaver Falls, Sept. 29, 1900. Caused foaming when concentrated.
11. Softened water. Foams when concentrated about 8:1.

METHOD OF ANALYSIS.

Our method of analysis, which has already been hinted at, is in outline, as follows:

Evaporation to dryness on the water bath. Treatment with boiling distilled water free from carbon-dioxide. Filtration and washing with boiling water. The residue is thoroughly rubbed up with a rubber-coated rod. If the water is high in sulphates, use plenty of hot water.

Dissolve the insoluble part in dilute hydrochloric acid. Determine iron, lime, and magnesia volumetrically in both soluble and insoluble portions. Express results as soluble and insoluble iron, lime and magnesia. Determine silica in separate portion.

Determine chlorine and sulphuric anhydride by usual methods.

Determine alkalinity or acidity by adding a measured excess of standard d. n. sulphuric acid to 100 c. c. of water, boiling 20 minutes in platinum or porcelain, and titrating back with decinormal sodium hydrate, using phenolphthalein indicator. Calculate acidity to sulphuric acid or alkalinity to calcium carbonate.

Determine nitric anhydride by the phenol-sulphuric method, using silver sulphate to remove chlorine before evaporation, and adding a little sodium carbonate to prevent loss in evaporation.

Free carbon-dioxide is determined if the sample has been sent in a sealed condition, so that the gas has not escaped. This is determined by titrating 50 c. c. in a nessler tube, with $\frac{1}{50}$ N. sodium carbonate. (Seyler's Method.)*

CALCULATION.

Our calculation of chemical treatment required for softening hard water or neutralization of acid water is based entirely on the amounts of free carbon-dioxide, soluble and insoluble lime and magnesia, free acid and iron.

About these there can be no discrepancy if our method of separating soluble and insoluble lime is followed and the analyses are accurate.

It is in the less important matter of arbitrarily disposing the acids among the bases that chemists differ. Our own practice is to calculate insoluble lime and magnesia to carbonates. The residual alkalinity is figured to sodium carbonate. There can be no argument about this. When, however, we have to decide how much of the soluble lime is combined with sulphuric anhydride or other acids, and the same for the soluble magnesia, we realize that we can no longer proceed logically, but must follow an arbitrary practice.

It is possible by using dilute alcohol for extraction of the original solid residue to leave calcium sulphate behind with the carbonates of lime and magnesia. This, however, seems to us of questionable advantage, as the separation of all sulphate of soda is difficult, and sulphuric acid has to be determined twice. We have not used this method, but if we undertook it we think that it would be best to make the separation by water first, then evaporate to dryness, and extract with alcohol.

Our arbitrary method of calculating is to give the soluble lime first sulphuric anhydride, then chlorine, then nitric anhydride until satisfied. Satisfy soluble magnesia in the same way with what remains, calculate residual acid radicals to soda, unless both soda and potash have been determined. In that case satisfy soda first.

The question is whether to recommend the introduction of the alcohol method into ordinary practice for the sake of actually determining sulphate of lime, or to figure all soluble lime to sulphate, if there is enough sulphuric acid present.

It may be supposed that calcium chloride and nitrate, and the corresponding salts of magnesia, including also the sulphate, do not form scale, and, therefore, need not be removed. In reply to this it may be said that it is doubtful whether any magnesium salts are stable under boiler conditions, and they should all be removed to prevent corrosion. It is difficult, if not impossible, to partially treat a water so as to leave calcium chloride and nitrate undisturbed. They are objectionable, as they change to sulphate if magnesium sulphate is present. They should, therefore, be removed.

The chemical equations involved in water softening are familiar to you all, but will, perhaps, bear repetition, as the necessity for certain points is often overlooked.

PURIFICATION BY LIME AND SODA. (THE CHEMISTRY OF THE PROCESS.)

Bicarbonate of lime requires one equivalent of slaked lime for its removal.

$$CaCO_3CO_3+CaH_2O_2=2CaCO_3+H_2O.$$

Bicarbonate of magnesia requires two equivalents of lime. The first liberates magnesium carbonate, and the second changes the somewhat soluble carbonate to hydrate, which is quite insoluble.

$$MgCO_3CO_3+2CaH_2O_2=2CaCO_3+MgH_2O_2+H_2O$$

Carbonic acid requires one equivalent of lime.

$$CO_2+CaH_2O_2=CaCO_3+H_2O$$

Free sulphuric acid, or sulphate of iron, requires one equivalent of lime and one equivalent of soda.

$$H_2SO_4+Na_2CO_3+CaH_2O_2=Na_2SO_4+CaCO_3+2H_2O$$
$$FeSO_4+Na_2CO_3+CaH_2O_2=Na_2SO_4+CaCO_3+FeH_2O_2$$

Soluble lime salts while not all scale-formers, are best removed when softening water. They require one equivalent of soda.

$$\left.\begin{matrix}CaSO_4\\CaCl_2\\CaN_2O_6\end{matrix}\right\}+Na_2CO_3=\left\{\begin{matrix}Na_2SO_4\\2NaCl\\2NaNO_3\end{matrix}\right\}+CaCO_3$$

Soluble magnesia salts require one equivalent of lime and one of soda.

$$\left.\begin{matrix}MgSO_4\\MgCl_2\\MgN_2O_6\end{matrix}\right\}+Na_2CO_3+CaH_2O_2=\left\{\begin{matrix}NA_2SO_4\\2NaCl\\2NaNO_3\end{matrix}\right\}+CaCO_3+MgH_2O_2$$

In calculating cost of water treatment, it is customary to figure to pounds of each chemical required for 1,000 U. S. gallons.

In the following table, I base my estimates on 90% lime and 95% soda ash; because, while you may buy the best grades of these materials, you are apt to get shipments which average as above. For preliminary work the following prices are used:

90% lime, at $5 per ton = 0.25ct. per lb.
95% soda ash, at $20 per ton = 1.00 ct. per lb.

PITTSBURGH TESTING LABORATORY METHOD FOR CALCULATION OF CHEMICALS REQUIRED FOR WATER SOFTENING, OR NEUTRALIZATION OF ACID WATERS.

Basis: Add one equivalent of lime for free carbon-dioxide, insoluble lime, insoluble magnesia, soluble magnesia, acid iron salts and free acid. Insoluble magnesia requires two equivalents of lime.

Add soda enough for soluble lime and soluble magnesia and free acid, including acid iron salts.

Iron present as carbonate is removed by the addition of an equivalent of lime.

Parts per 100,000.	Pounds for 1,000 U. S. Gallons.
CaO, insol (*i.e.*, as carbonate), MgO, insol, (*i.e.*, as carbonate)	x.0925=Com'l lime, 90% CaO
MgO, soluble (*i.e.*, as sulphate), MgO, soluble (*i.e.*, as chloride), MgO, soluble (*i.e.*, as nitrate)..	x.13 " " " "
Acid, free (calculated as H_2SO_4)	x.053 " " " "
CO_2, free	x.118 " " " "
Fe as carbonate)	x.064 " " " "
CaO, soluble	x.103=Soda ash, 95% Na_2CO_3
MgO, soluble	x.233 " " " "
Acid, free	x.095 " " " "

At 15° C., saturated limewater=1.3 g. per liter.
At 15° C., saturated limewater=1.083 lbs. per 100 gallons.

The solubility of lime in water varies slightly.

ARCHBUTT'S METHOD FOR CALCULATION OF CHEMICALS REQUIRED FOR WATER SOFTENING.

As much sodium carbonate is dissolved in a little water as is equivalent to the total lime and magnesia, deducting as much as is equivalent to the total alkalinity of the water.

Lime water enough is added to give a straw color with silver nitrate, and then as much more as is equivalent to the magnesia present. This would, apparently, lead to the same results as would be obtained by our method of calculation. We have not tested it.

Returning to a further consideration of the method in which it is best to state the results of chemical analyses of water, it may be admitted that the simple statement of basic and acid radicals actually found will be safest and wisest in some cases.

In a very great number of instances, however, the client desires to have the analysis show the most probable combination of bases and acids. He wishes to know what salts are in the water, so that its medicinal or technical uses may be intelligently understood.

For this reason it is desirable that chemists should get together and agree upon a method of expressing results.

Cairns, "Quantitative Analysis," 1888, p, 182, follows this plan, which he says meets most cases:

Combine the sodium with chlorine as sodium chloride and the potassium with sulphuric acid as potassium sulphate. Should there be any more sodium than chlorine, and more sulphuric acid than is required by potassium, combine the excess with sodium, and if there is more sodium left, combine it with carbonic acid.

Should there be more than enough sulphuric acid for both sodium and potassium, combine excess first with calcium as calcium sulphate, and next with magnesia as magnesium sulphate.

If chlorine is more than enough to satisfy sodium, combine it with potassium if sulphuric acid was not sufficient.

If chlorine is still in excess, combine it with magnesium and then with calcium. Calculate all calcium and magnesium, not combined with chlorine, and sulphuric acid, as carbonates.

This method may be criticized in that it makes no provision for nitric acid if present, and that it does not take advantage of the absolute knowledge which may be gained by analysis, as to the amounts of calcium and magnesium present as carbonates. The method is based on Fresenius's earlier recommendations. In the latest* edition of Fresenius the following example of a water analysis calculation is given. The author determines the calcium precipitated by boiling, and calculates it to carbonate. Beyond that he attempts to combine acids and bases according to relative affinities and solubilities:

1. Barium calculated to sulphate of barium.
2. Strontium calculated to sulphate of strontium.
3. Residual sulphuric acid calculated to calcium sulphate.
4. Bromine calculated to magnesium bromide.
5. Iodine calculated to magnesium iodid.
6. Calcium not precipitated by boiling, and not already figured to sulphate, is calculated to chloride of calcium.
7. Potassium calculated to chloride of potassium.
8. Lithium calculated to chloride of lithium.
9. Ammonia calculated to chloride of ammonium.
10. Sodium calculated to chloride of sodium.
11. Residual chlorine calculated to magnesium chloride.
12. Phosphoric anhydride calculated to phosphate of calcium.
13. The calcium found in the precipitate on boiling, minus the amount required by phosphoric acid, is calculated to carbonate.
14. The magnesium not calculated to bromide, iodide or chloride is figured to carbonate.
15. The iron found is calculated to carbonate.
16. The manganese found is calculated to carbonate.
17. The silica found is calculated as silica.
18. The free carbonic acid is calculated by deducting from the total the amount required by the lime, magnesia, and iron to form bicarbonates. In alkaline waters the phosphoric acid is calculated to phosphate of alumina. In saline waters it is figured as phosphate of calcium.

The scheme given above was used in connection with a mineral water analysis. No provision is made for nitric anhydride.

FRESENIUS'S GENERAL RULE FOR WATER ANALYSIS CALCULATION.

This is supposed to apply to technical analyses where the rarer elements are not determined, and is given in the 1900 edition.

If the water is alkaline all of the calcium and magnesium present are calculated as carbonates. Otherwise proceed as follows:

1. Combine all chlorine with sodium.
2. Combine excess chlorine with calcium.
3. Combine sulphuric acid with calcium.
4. Combine nitric acid with ammonium, and then with calcium or magnesium, if necessary.
5. The remaining lime and magnesia are calculated as carbonates.

This rule is very incomplete, in that it does not provide for the disposal of the sodium which might be in excess of the chlorine. It is also silent on the disposition of sulphuric acid in excess of the amount required by calcium, and of nitric acid in excess of the amounts required by the bases enumerated. The first illustration is much more complete.

There seems to be a feeling among the followers of Fresenius that in general the sodium and potassium should be the first bases to be provided for, and they are generally given the chlorine or sulphuric acid, or both if necessary.

The method of analysis used in the Kennicott laboratories is shown on a chart recently sent out for criticism. It differs from plans in general use, in that it provides for the determination of the amount of calcium sulphate actually present. This is accomplished by the use of alcohol of .92 specific gravity as a solvent for treating the dry residue. Silica, carbonates of lime and magnesia and sulphate of lime are insoluble in this menstruum. They are afterwards separated, the determination of sulphuric anhydride being the index to the amount of calcium present as sulphate.

This removes one more arbitrary step from water analysis calculation, but it is accomplished at the expense of some time and considerable alcohol. It does not affect water softening calculations at all, but it is designed to give certain information regarding the most important scale-forming compound which occurs in waters. The actual value of the alcohol used for each analysis would be from six to ten cents, which is not so serious a matter as would at first appear.

The fact that three hours are required for the extraction, indicates that sulphate of soda and the other soluble salts do not dissolve rapidly, and errors due to incomplete extraction would have to be guarded against by tests, as suggested.

The scheme makes no provision for calculation of nitrates, but it seems to the writer to be commendable in other respects. If the plan could be elaborated further to allow discrimination between magnesium chloride, sulphate and nitrate, nothing would be left to the analyst's judgment. This, however, is hardly to be hoped for, and it is, therefore, desirable to have the necessarily arbitrary calculations all made by the same method.

ORDER IN WHICH BASES ARE APPORTIONED TO ACIDS BY SEVERAL ANALYSTS.

	Sulphuric Acid.	Chlorine.	Nitric Acid
Cairns	1. Potassium	Sodium.	.....
	2. Sodium.	Potassium.	.....
	3. Calcium.	Magnesium.	.....
	4. Magnesium.	Calcium.	.....
Fresenius	1. Barium.	Calcium.	.....
	2. Strontium.	Potassium.	.....
	3. Calcium.	Sodium.	.....
	4.	Magnesium.	.....
Pittsburg Testing Laboratory	1. Calcium.	Calcium.	Calcium.
	2. Magnesium.	Magnesium.	Magnesium.
	3. Sodium.	Sodium.	Sodium.
	4. Potassium.	Potassium.	Potassium.
Kennicott	1. Calcium.*	Calcium.	.....
	2. Magnesium.†	Magnesium.	.....
	3. Sodium.	Sodium.	.....

For technical work direct determinations of sodium and potassium are not usually made. The residual acids not

*"Estimation of Carbon Dioxide in Water," Ellms and Benneker, Jour. Am. Chem. Soc., 1901, p. 405.

*"Traite de l'Analyse Quantitative," R. Fresenius, 7th French from 6th German ed., 1900.

* Calcium calculated from sulphate insoluble in alcohol.
† Magnesium figured to sulphate is the amount left over after figuring the magnesium combined with chlorine.

required for the bases found are calculated to sodium salts.

LABORATORY SOFTENING TESTS.

After obtaining a correct chemical analysis of any water which is to be softened, and making a calculation of the kind and amounts of chemicals required for its purification, it is best to soften a sample of water in the laboratory. If, however, we simply mix the chemicals and water in the proper proportions, and let the mixture stand, the completion of the chemical reaction will take many hours. It is necessary to take advantage of the beneficial influence of agitation with crystalline sludge in order to determine quickly the correctness of our calculation.

The lime water used should be made from the water which is to be softened. If softened water is to be used in the lime saturator of the apparatus, it must also be used in the laboratory test. One gram of crystalline sludge is mixed with about 250 c.c. of water plus the necessary reagents. The mixture is shaken vigorously for ten minutes or stirred for half an hour by mechanical means. Filtration follows, and an aliquot portion of the filtrate is analyzed to determine whether the lime and magnesia have been removed to the degree expected. The soap test, the alkalinity test and the silver nitrate test will tell what change in reagents is necessary.

It must be remembered that free carbonic acid will exist in larger quantity in a fresh sample of water. The total amount of lime required for treatment must be determined on fresh samples, tested at the source.

The fact that the design of the machine depends upon the speed and completeness of the softening should not be lost sight of in a laboratory test. The period of stirring and time of standing practically quiet should be the same which is to be allowed in the machine. These factors can be varied if necessary. It will then be possible to judge with sufficient accuracy what the rate of softening is, and from this what size of machine will be necessary. In this "speed of reaction" experiment not over 0.2 gr. of sludge should be present for 500 c. c. of mixture.

CHEMICAL CONTROL OF SOFTENING PLANTS.—DETERMINATION OF HARDNESS.

Soap Solution.—Dissolve 13 grams of pure, powdered castile soap in one liter of 50% alcohol (half alcohol and half water). Let stand over night and filter.

Standardization.—Dissolve one gram of pure calcium carbonate in a slight excess of dilute hydrochloric acid. Evaporate to dryness. Dissolve in boiled, distilled water; make up to one liter: 1 c. c. = .001 gm. of calcium carbonate.

Pour 12 c. c. of this solution in a stoppered bottle (preferably one of about 500 c. c. capacity, of square section and about twice as high as wide). Dilute to 100 c. c. with distilled water. Run in soap solution from a burette, shaking well after each addition, until there is formed a lather which is permanent for three minutes after opening the bottle and laying it on its side. Twelve c. c. of soap solution should be required. If less is needed, dilute the entire soap solution with 50% alcohol in the proportion indicated by the test.

The Hardness Test.—Place 100 c. c. of water in the bottle, add the soap solution as above. If more than 14 c. c. of soap solution is required, repeat the test, using 50 c. c. of hard water diluted to 100 c. c. with distilled water. If more than 14 c. c. is still required, use 25 c. c. of the original water and dilute to 100 c. c. for test.

The cubic centimeters of soap solution used for 100 c. c. of water indicate the hardness expressed in parts of calcium carbonate per 100,000. (This represents Kennicott practice, except that we have recommended preparing calcium chloride from the carbonate.)

Determination of Alkalinity.—One hundred c. c. of treated water are titrated with decinormal sulphuric acid, using successively phenolphtalein and methylorange as indicators. The second end point is best taken when the clear yellow solution just changes to orange on its way to a clear pink. The methylorange solution is made by dissolving 0.1 gram of the powdered material in 100 c. c. of 50% alcohol. For general work this gives very satisfactory results. For more exact work in the laboratory use the method given below for alkalinity or acidity. For alkalinity tests of hard water when the titration is made in the cold, methylorange indicator is used.

Determination of Acidity.—Titrate 100 c. c. of water with d. n. sodium hydrate, using phenolphtalein as indicator. This gives the acidity due to free sulphuric acid, sulphate of iron and free carbon dioxide. As the latter is usually quite small in amount, it is disregarded in control work at softening plants.

Alkalinity or Acidity Determination.—In order to get the acidity or alkalinity of a water most accurately, it is best to add to 100 c. c. of water a measured excess, e. g., 5 c. c. of d. n. sulphuric acid. Add three drops of phenolphatein solution, boil twenty minutes in a porcelain or a platinum dish, cool and titrate with d. n. sodium hydrate. The increase in acidity is the measure of the acidity of the water. The decrease in acidity is the index to the alkalinity of the water. By "measured excess" of acid is meant acid in excess of that required by direct titration with sodium hydrate when using methylorange as indicator.

Silver Nitrate Test.—Silver nitrate gives a yellow color or a brown precipitate when added to water containing free calcium hydrate. This is useful in connection with alkalinity and hardness tests. If the alkalinity to the phenolphtalein end point is above the normal, and the silver nitrate test shows a colored precipitate, too much lime is being used.

Examination of Lime Water.—Total Calcium Hydrate: Draw a sample of about 50 c. c. of lime water. Unless clear add approximately 0 grams of cane sugar. Cork the bottle and shake for two minutes. Filter through a dry paper into a dry vessel. Titrate 21 c. c. with decinormal sulphuric acid, using phenolphtalein indicator. If approximately 10 c. c. of acid are required the lime water is of full strength or 100%. If more than 10 c. c. of acid are required, the result shows calcium hydroxide in suspension as well as solution. Such a state of affairs indicates too large an excess of lime in the lime saturator, or too rapid or uneven a flow.

If 21 c. c. of lime water require less than 10 c. c. of acid, it is not saturated, and probably the lime supply is low. This relation of 21 to 10 varies somewhat with different waters, and should be determined under actual conditions always.

The use of sugar as a solvent for calcium oxide in connection with the analysis of quick lime was suggested by Stone and Scheuch in 1894.* The originators of the method used methylorange or rosolic acid. We prefer phenolphtalein as indicator.

Oxide and carbonate of magnesia are insoluble in sugar solution, and carbonate of lime is not appreciably soluble.

Analysis of Lime.—Lime will be received in barrels or in bulk, according to the amount used. It should be stored in a dry room, preferably one lined inside with metal sheathing.

Shipments are sampled as received. If in barrels, take three lumps from each of five barrels. If in bulk, select 15 lumps to represent the car load. Crack off approximately equal-sized pieces from each lump. Crush, mix, quarter and grind. Bottle half an ounce of the average sample after grinding to pass 100 mesh.

Weigh out 0.28 gram. Place in an erlenmeyer flask exactly 100 c. c. of 10% cane sugar solution. Add the lime to this, shake until no further solution is apparently taking place. If any lime sticks to the bottom it will be slow in dissolving. Sticking can be avoided by continuous and rapid movement of the liquid.

Filter 50 c. c. and titrate with decinormal sulphuric acid. Multiply c. c. used by two. Result shows per cent. of available calcium oxide, which is the measure of value of the lime when used for water softening.

Analysis of Soda Ash.—Dissolve 0.53 gm. of a well-mixed average sample in water and make up to 100 c. c. with cold distilled water. Titrate 50 c. c. of this with d. n. sulphuric acid, using methylorange as indicator. Multiply c. c. of acid used by 2 to get percentage of sodium carbonate in the soda ash.

IV.—Two Municipal Water-Softening Plants.

THE MUNICIPAL SOFTENING PLANT AT SOUTHAMPTAN, ENGLAND.†

The city of Southampton, England, with a population of about 70,000, is supplied with water softened by the Clark process. The plant is continuous in operation. It was installed in 1888, and was worked for several years according to W. Geo. Atkins' plans. It was designed for 2,500,000 imperial gallons per day. It has been modified by Mr. William Matthews so that it now treats 4,000,000 gallons per day.

The plant and the method of operation in August, 1901, were reported to be as follows:

Lime burned in two kilns from chalk quarried on the premises is stored in a moisture-proof room. Measured quantities are periodically slaked in a revolving cylinder with a definite amount of water and pumped to the lime water tanks, of which there are four, each being 11 ft. high by 9 ft. in diameter, and terminating in a 3 ft. cone at the bottom. They hold about one hour's supply of lime water, but are furnished with lime cream enough at one time to last six hours, the lime water being formed by running water through.

Softened water from the high pressure main is used for making lime water. Two pounds of lime are required per 1,000 gallons of water softened. The water is reduced from 18° hardness to about 5°. With such cheap lime the re-pumping of 12% of the water for making lime water is a very questionable economy. Matthews‡ claims that lime water made with soft water clarifies sooner. We did not find it so.

The proportion of lime water to hard water is regulated by weirs, but not automatically. The weirs simply indicate the rates of flow, and by valves the ratio is kept as it should be. This method may have been replaced by the use of a proportional pumping device. No chemical tests of lime water are made to ascertain whether things are going right. Only the most uniform lime supply and rate of pumping could make success possible under these conditions.

The hard water and lime water are mixed by flowing through a passage with baffles, and the mixture then falls into the "Softening Tank," 44 ft. × 76 ft. × 6½ ft. deep. A baffle wall makes the course of the water first down nearly to the bottom and then forward some 70 ft. to the filter house. The tank holds only about 135,000 gallons, which, at a 4,000,000 gallon per day rate, means only about 50 minutes' supply. This is a remarkably short time for chemical action, but the water is reported clear and tasteless after filtration, and showing no after-reaction.

The filters seem to be rather cumbersome, but are remarkably efficient. They are of Atkins' design. Nineteen are used. According to Fuertes,* each filter consists of a hollow shaft, having longitudinal slots, on which is mounted a series of perforated zinc disks 3 ft. in diameter and separated from each other by collars. Over the disks cotton cloths are stretched and held by iron rings pressed over edges. There are 20 disks and 40 cloths to each filter.

The filters are placed in iron tanks, one end of the shaft passing through a stuffing box and communicating with the small filtered water basin below. The shaft and disks may be rotated by gearing, and the whole may be lifted out by an overhead crane, when the cloths are to be replaced. The filters thus work, submerged in water, filtering inward, and they have to handle practically three tons of precipitate daily, because little, if any, settles in the large tank. When clogged, the filter-tank is drained and the cloths rinsed off with water from a hose, the sludge and excess water being separated in tanks below. The water is pumped back and the sludge run to waste.

The cloth used for the filters is a cotton of medium weight and weave, and of somewhat rough finish. Its life averaged three months when 3,000,000 gallons of water were being used daily. This meant 50 sq. ft. of cloth per day on 5 000 sq. ft. in use.

This high duty of the filters under practically no head would not be possible for a moment if the water were magnesian, as it is at Winnipeg. Our sludge is like lard in smoothness and fineness, while the Southampton sludge is all crystalline calcium carbonate. It is probable that the great speed and completeness of the softening are made possible by the presence of the clean crystals of carbonate of lime in suspension in the water during the whole time in the tank, and also by the passage of the water through the crystals on the cloths. If the water had contained magnesia as well as lime, the whole process would have gone quite otherwise.

The cost of softening at Southampton is said to be only 1 ct. per 1,000 gallons. Lime costs them approximately 0.25 ct. per 1,000 gallons. The investment originally was £10,000, and there have been improvements since then. The interest and depreciation charges would be 0.84 ct. Re-pumping, say, 12% of the water means 300,000 gallons raised from filtered water basin to top of lime water tanks. The lift would be about 25 ft. and the cost not less than 0.12 ct. per 1,000 gallons output. There is the waste of water in the sludge and the cost of power used about the plant for running the lime slaker, lime pump and sludge pump. Besides these items the labor cost cannot be less than 0.3 ct. per 1,000 gallons.

We do not see how the cost can fall below 2 cts. per 1,000 gallons of water softened, but even at this figure the result reflects credit on the designers of the plant.

MUNICIPAL SOFTENING PLANT AT WINNIPEG, MANITOBA.

In September, 1897, Mr. Rudolph Hering, M. Am. Soc. C. E., made a report to the city of Winnipeg, Manitoba, on a "Future Water Supply." The city authorities at that time were considering the purchase of the plant of the private company which had been supplying them with Assiniboine River water. The river supply had been of unsatisfactory character, and Mr. Hering was asked to compare all available sources. His examination satisfied him that the artesian supply undoubtedly to be had just west of the city would be the cheapest and best, but that it would be necessary to soften the water. The total expense was still calculated as sure to be less than that of bringing soft water 50 miles from the Winnipeg River.

The advantages of soft over hard water for a community were stated by Mr. Hering as follows:

Hot water is obtained more quickly and less fuel is required. The saving of soap and soda in the household is considerable. The labor of washing is much reduced. The wear and tear of clothing is diminished. Flannels last longer and do not become harsh and felted. Cooking is facilitated. The same quantity of tea that will make three cups with hard water will make five cups with soft water. (Evidence before Royal Commission.) The palatability is often increased. The softening process does not make water insipid.

Mr. Hering estimated the cost of softening the artesian well water at 2.57 cts. per 1,000 gallons, and the cost of a softening plant at $27,000, exclusive of the building. It would cost a family of five persons using 300 gallons of water daily less than 1 ct. for softening, and if 100 gallons of this were used for washing purposes, 1½ lbs. of soap, worth, at least, 7 cts., would be saved.

The City Council of Winnipeg accepted Mr. Hering's recommendations, and in the Spring of 1899 advertised for bids for pumping engines, boilers and a softening plant.

A few railroad and industrial softening plants had been

*"A Method for the Determination of Calcium Oxide in Quicklime," Jour. Am. Chem. Soc., 1894, p. 721, Stone and Scheuch.

†This plant was described and illustrated in Engineering News of April 16, 1892.

‡"Southampton Water-Softening Plant," Matthews, Proc. Inst. Civ. Engrs., Vol. CVIII., 1891-2.

*"Water Softening at Southampton," J. H. Fuertes, Eng. Rec., Feb. 2, 1899.

built in the United States up to that time, and in England the Southampton municipal plant was in existence. The idea was, however, new enough in both the United States and Canada, so that the city engineer, Col. H. N. Ruttan, had to personally solicit bids in order to have any competition. Four were finally secured, and the offer of the Pittsburgh Testing Laboratory, Limited, was accepted.

The city water, in its natural state, has a temperature of 42° F., and is of the following composition:

	Parts per 100,000.
Free carbon dioxide	2.20
Silica	.28
Carbonate of lime	20.30
" " magnesia	11.30
" " soda	3.99
Sulphate of lime	0.60
" " magnesia	17.25
" " soda	6.59
Chloride of sodium	29.60
Total solids	99.91

Temporary hardness=23.63° (Clark's scale).
Permanent hardness = 10.37° (Clark's scale).
Total hardness = 34.00° (Clark's scale).
Maximum hardness removable by lime process, 23.63°.
Maximum hardness actually removed by P. T. L. Plant, 22.73°—96.2%.
Average hardness removed, 24-hour test, 21.28°—90.1%.

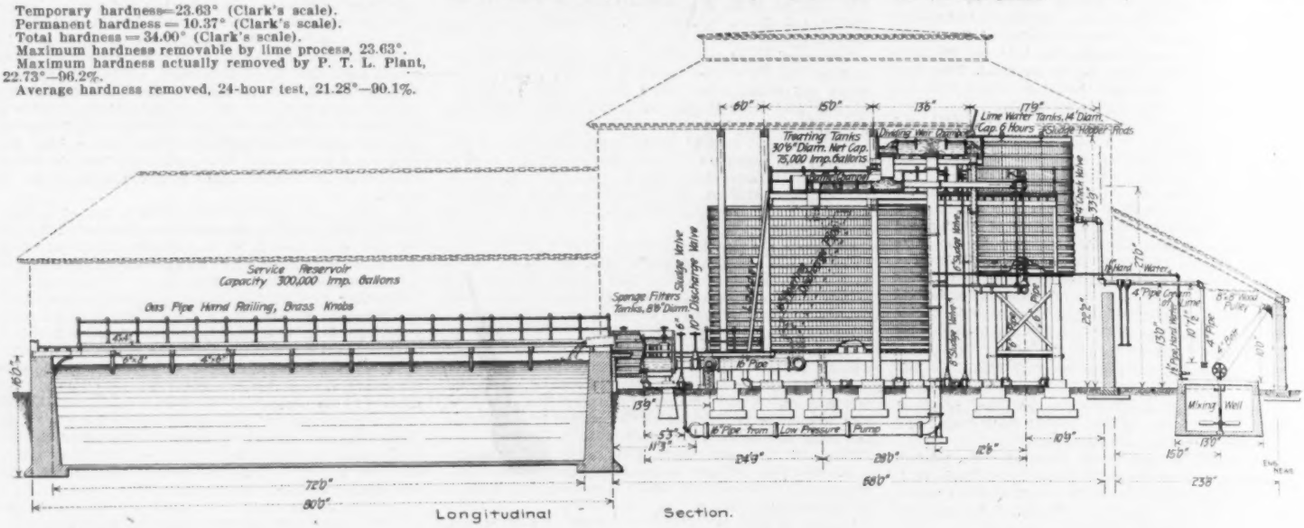
However, more severely taxed when the rate exceeded 2,400,000 gallons in 24 hours.

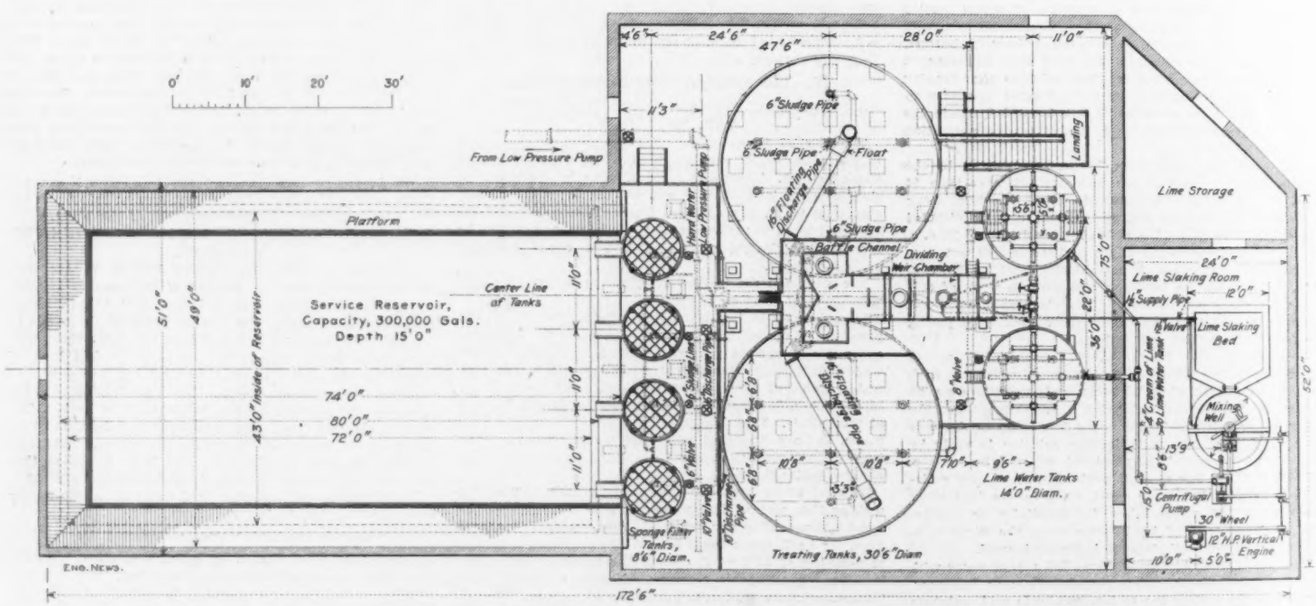
PROCESS ADOPTED.

It was decided that the softening process should be limited to the removal by lime treatment of the maximum possible amount of the bicarbonates of lime and magnesia from the water, leaving the magnesium sulphate undisturbed. For this purpose the Clark process was used.

The chemical basis of the method is as follows: Water falling as rain dissolves some carbonic acid gas from the atmosphere. It takes up more of the gas as it sinks into the soil, and when it is in a country where it comes in contact with limestone, which consists of carbonate of lime and magnesia, it dissolves some of the carbonates out of the rock and becomes a hard, soap-destroying and scale-forming water. This result is made possible by carbonic acid gas. If now any substance can be added to this hard water to absorb the carbonic acid, the carbonates of lime and magnesia which it held in solution are hydroxide still retains its affinity for carbonic [illegible]. If added to hard water it unites with this gas with great avidity, forming an insoluble compound (carbonate of lime) which separates from the water. At the same time the carbonates of lime and magnesia which were held in solution in the hard water by the carbonic acid are set free, and they also settle out of the water if allowed proper opportunity to do so.

Calcium hydroxide (slaked lime) is only sparingly soluble in water. Hence in applying it for water-softening purposes it is sometimes used in mixture with water as cream or milk of lime. This is the form in which it is usually employed in the "intermittent" systems of water softening. In the continuous systems, however, advantage is taken of the fact that a saturated solution of lime in water (lime water) has a perfectly definite strength at any given temperature. This averages for cold water about 1.3 grs. per liter, or 1.083 pounds per 100 U. S. gallons, or 1.3 pounds per 100 Imp. gallons.





Sectional Plan.

GENERAL PLAN AND ELEVATION OF WATER-SOFTENING PLANT FOR THE MUNICIPAL WATER SUPPLY OF WINNIPEG, MAN.
Designed by the Pittsburg Testing Laboratory, Ltd.

CAPACITY OF PLANT.

The plant was guaranteed to have a capacity for softening 2,400,000 imperial gallons (2,880,000 U. S. gal.) per day, and to furnish softened water at a rate 50% greater than this for several hours when required. We not only ran successfully for four hours at the highest guaranteed rate, 3,600,000 gallons per day, but also ran up to a 4,000,000 gallon rate for a shorter period. The degree of softening was 22.2°, at the 3,600,000-gallon rate. This was 93.99% of the result theoretically possible. The chemical reaction was equally satisfactory at both high and low rates of running. The filter capacity was, however, more severely taxed when the rate exceeded 2,400,000 gallons in 24 hours.

PROCESS ADOPTED.

It was decided that the softening process should be limited to the removal by lime treatment of the maximum possible amount of the bicarbonates of lime and magnesia from the water, leaving the magnesium sulphate undisturbed. For this purpose the Clark process was used.

The chemical basis of the method is as follows: Water falling as rain dissolves some carbonic acid gas from the atmosphere. It takes up more of the gas as it sinks into the soil, and when it is in a country where it comes in contact with limestone, which consists of carbonate of lime and magnesia, it dissolves some of the carbonates out of the rock and becomes a hard, soap-destroying and scale-forming water. This result is made possible by carbonic acid gas. If now any substance can be added to this hard water to absorb the carbonic acid, the carbonates of lime and magnesia which it held in solution are set free and fall as a white precipitate out of the water, leaving it nearly as soft as it was originally.

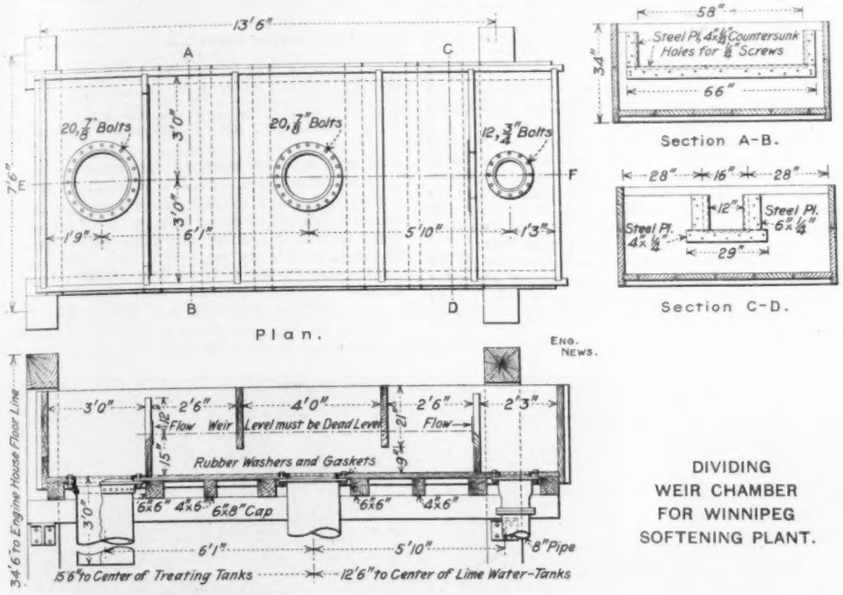
Two chemical agents are capable of doing this. One is sodium hydroxide, commonly called caustic soda, and the other is calcium hydroxide, commonly called slaked lime. The treatment by soda costs 14 times as much, and is objectionable for other reasons. Therefore, the lime process is used. Builders' lime is made by driving off the carbonic acid from limestone in kilns. It has a great affinity for both water and carbonic acid. When uniting with water to form calcium hydroxide heat is developed. The process is called slaking. After the slaking the calcium hydroxide still retains its affinity for carbonic acid. If added to hard water it unites with this gas with great avidity, forming an insoluble compound (carbonate of lime) which separates from the water. At the same time the carbonates of lime and magnesia which were held in solution in the hard water by the carbonic acid are set free, and they also settle out of the water if allowed proper opportunity to do so.

Calcium hydroxide (slaked lime) is only sparingly soluble in water. Hence in applying it for water-softening purposes it is sometimes used in mixture with water as cream or milk of lime. This is the form in which it is usually employed in the "intermittent" systems of water softening. In the continuous systems, however, advantage is taken of the fact that a saturated solution of lime in water (lime water) has a perfectly definite strength at any given temperature. This averages for cold water about 1.3 grs. per liter, or 1.083 pounds per 100 U. S. gallons, or 1.3 pounds per 100 Imp. gallons.

The problem at Winnipeg, therefore, was to apply the proper proportion of lime to the water in a uniform manner. This we accomplish as follows: Lime, purchased by the car load, is discharged into the lime store room shown at the corner of the plan. It is weighed out 375 lbs. at a time, and slaked in a slaking bed with hot water, after which it is made up to a definite volume and run through a screen into the mixing well. Here it is kept in suspension, by a stirrer operated by a 12 HP. engine, also used to run the washing machine and blower and lime tank stirrers.

From the mixing well the cream of lime is forced up

by means of a special ball valve pump to the weir box, where it meets the water which is to be made into lime water, and the mixture passes to the bottom of the two lime tanks. Here a small excess of lime is maintained to take care of a sudden increase in rate of pumping. The lime tanks are 14 ft. in diameter by 18 ft. deep. They have cone bottoms inside and stirrers with paddles, which revolve slowly in these cones, the idea being to maintain an even cream of lime at the bottom. Through this the nearly saturated lime water flows, and becoming saturated continues upward, clarifying as it rises. The impurities



DIVIDING WEIR CHAMBER FOR WINNIPEG SOFTENING PLANT.

and excess lime theoretically remain behind, but actually a small amount of lime is always present in suspension, and in our method of chemical control this is always taken into account.

The lime water, made as described, overflows constantly at a point about 5 ft. above the level of the reaction tanks, as shown. It passes forward through an 8 in. pipe line and meets the hard water in a baffle channel just below the weir box, which will be described later.

In the baffle channel the hard water and lime water are most thoroughly churned and mixed together. The softening process begins instantly, and is perhaps nine-tenths finished before the water divides and passes into the two 20 ft × 30 ft. reaction tanks.

It enters these through chutes, the proper shape for which was only determined after much experiment. Each chute, 22 ins. in diameter, conveys the water to a point 36 ins. from the tank floor and turns sidewise, following the curve of the tank for 10 ft., gradually flaring out to a flattened oval, 3 ft. wide by 1 ft. high. Into the quiet area below the chute, most of the precipitate settles at once. All but a trace of the remainder, so far as appearance goes, settles out during the rise of the water through the tanks.

The nearly clarified water flows off through floating draw-off pipes at the top of the tanks. These pipes have T-shaped slotted pipes, extending over the surface of the tank to make a more even draft, and to avoid eddies.

The water, now under about 17 ft. head, flows to the filter presses, which clarify it perfectly. These presses are of special design and of capacity probably unequaled for their size. Their duty is to remove a minute amount of precipitate rapidly from a very large volume of water—just the reverse of the work of an ordinary filter press. There are seven presses, 15 ft. × 3 ft. × 3 ft., and each one has 80 plates. Cloths, made of 10 oz. duck, are placed over each frame, giving a total filter surface, after deductions for holes, etc., of about 1,000 sq. yds. These filters run from 24 to 48 hours before cleaning is necessary, the average number being two or three filters cleaned for each 24 hours' run. This means a 500,000 gallon delivery for each filter between cleanings.

The water passes into the presses at the ends, and finds a continuous opening through all the plates the length of the press. From this channel it must find its way down between the cloths, then through any cloth into the open grill work of the frames, from which it drops out into a trough discharging into the carbonating box. The object of carbonating is explained further on. The method is as follows; the process and apparatus were devised by the writer:

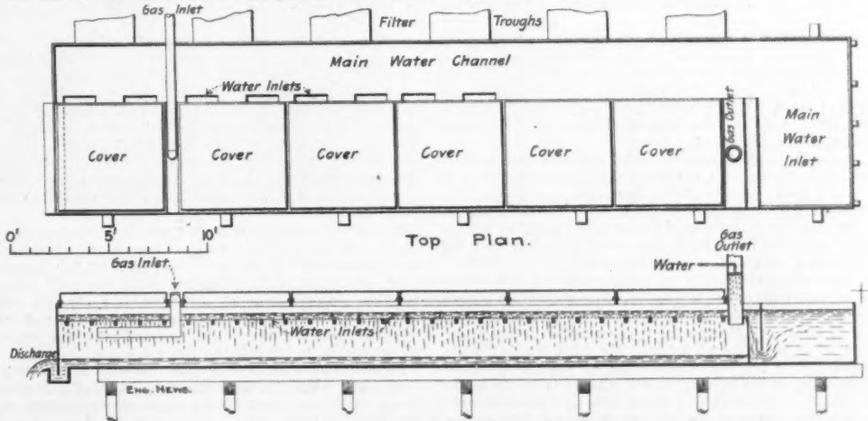
THE CARBONATING PROCESS.

Coke is burned in a small brick furnace. The gases are drawn by a Buffalo blower and exhauster through a water-jacketed condenser or cooler. From the blower the gases pass to a wooden wash tank, where the sulphurous acid is removed by streams of water dripping over 2 ft. of coke on a shelf. The wash tank is 6 ft. high by 6 ft. in diameter. Water enters through a copper spraying nozzle above the coke and flows off through a trap at the bottom. The gases enter just below the coke and pass away at the top by a wooden pipe, which conducts them to the carbonating box.

The carbonating box is placed across the end of the reservoir next to the filter presses. The water flows from the filters into a distributing trough, 3 ft. deep by 40 ft. long by 2 ft. wide. From this it flows through gas seals on to a perforated shelf, 6 ft. × 35 ft., with sides 8 ins. high. The shelf is made of heavy gage galvanized iron punched with 3-32-in. holes, the burr being left on to prevent the streams of water from running together. There are about 360 holes per square foot, or 73,000 all together. These carry a 3,600,000-gallon rate easily.

The greater part of the water flows onto the shelf at one end. A small part is introduced through openings along the side. This was done in order to cover the shelf evenly in spite of the great variations in pumping rate.

Six water-sealed covers enclose the perforated shelf, so



BOX FOR CARBONATING SOFTENED WATER.

that the gases entering below the shelf near the exit end of the box are forced to travel the whole length of the box through the small streams of falling water. This is more clearly apparent from the drawing.

The gases can come into the space above the shelf, but there is no exit for them there, and hence no circulation. The current of gas, therefore, passes through the box below the shelf, and the carbonic acid is very effectively dissolved by the falling water before the gas-exit pipe is reached.

This method of carbonating was the result of a very long series of experiments by the author. Conditions required that the carbonating should be completed while the water was on its way from the filters to reservoir. The available fall was very slight. Complete carbonating is effected in a 2-ft. 4-in. fall in this apparatus.

The carbonating plant was installed by us after the plant had been accepted by the City of Winnipeg. After-reaction had produced slight but annoying incrustations on the valves and condenser of the pumping engine. These deposits were the cause of sticking valves or imperfect vacuum. In a few instances deposits on meters, etc., in the city proper, took place.

The carbonating process, by changing the water from alkaline to neutral, made it impossible for any after-reaction to take place. Trouble from that source ceased at once. The water was absolutely tasteless when carbonated.

The service reservoir, into which the softened and carbonated water discharges, holds 300,000 gallons when filled to a depth of 15 ft. From the far end of it the water is drawn off by high-duty Worthington pumps and forced directly into the mains. There is no stand pipe or auxiliary reservoir, so that the engines, in maintaining a uniform water pressure in the mains, have to meet the greatest variations in rate of consumption, and the softening plant had to be made to operate satisfactorily under such conditions. At times of fire or a break in a main the pumping rate would necessarily be the maximum, and the work required of our plant especially severe.

It was not the high rate of pumping but the great changes in rate which made difficulties for us. How we met these troubles will be related further on.

The weir box, designed by Mr. Bellows, is one of the best features of the plant. It insures an absolutely proportional lime water treatment. It consists of a box 15 ft. long × 6 ft. wide × 2 ft. 6 ins. deep, located 33 ft. above the floor of the plant. Into the bottom of this comes the hard water through a 16-in. rising main. Baffle plates take the wave motion out of the water and then it flows uniformly over two weirs near opposite ends of the box. The weir openings are faced with adjustable, steel side-plates. The weir blades are exactly 15 ins. above the bottom of the box. The best ratio of lime water to hard water having been found by analysis and experiment to be 18:82, the weirs were set in this ratio, the combined width of the two being 70⅝ in.

The water falling over the lime water weir meets immediately a stream of cream of lime sufficient to saturate it under normal conditions. This lime water flows down through a 10-in. pipe and continuously displaces lime water already made and clarified in the two lime water tanks previously described. If 300 gallons of water go over the lime water weir, 300 gallons of saturated lime water flow forward from the top of the lime water tanks and meet an exactly proportionate amount of hard water flowing from the weir-box through a 20-in. pipe into the baffle-channel. Here they mix and go forward to the reaction tanks as described. It is impossible to get the wroug proportion of lime water. With a fairly uniform pumping rate it would be easy to keep the lime water of exactly even strength, i. e., always at the saturation point. As the rate of pumping varies widely, some chemical supervision is necessary, such as occasional tests of lime water and variation of the speed of the cream of lime pump to suit the changing conditions.

We placed on the side of the weir box a gage graduated to tenths of an inch. The fluctuations between 2.5 ins. and 6 ins. covered the range betwen 1,000,000 gallons and 3,750,000 gallons per day. A small box with a 1-in. weir served to measure the cream of lime flow. We put a gage on this as well and found that the feed was proper if the cream of lime gage reading was kept at half that of the main weir gage. It was only necessary to adjust the cream of lime feed at intervals. The strength of the cream of lime was about 0.5 lb. actual calcium oxide per U. S. gallon.

The lime water was tested every hour or oftener if unexpected fluctuations in pumping occurred. Samples for test were drawn from points about 8 ft. above the bottom

of each lime water tank, experience having shown us what the strength should be at this point in order to give saturated lime water on top. These were called "bottom" tests. Occasional "top" tests of finished lime water were also made, the method in all cases being as follows:

LIME WATER TESTS.

Two-ounce samples of lime water were shaken in bottles with approximately 5 grams of cane sugar. This caused all suspended calcium hydroxide (or active lime), to go into solution, leaving sludge undisturbed. The solution was then filtered and 21 c. c. of the filtered lime water tested with standard decinormal sulphuric acid, phenolphtalein being used as indicator. This test is simple and was quickly learned by the men. If 21 c. c. require 11.5 of acid, the strength is 115, which is proper for a "bottom" test. If the test shows less, more cream of lime must be turned on. If the test is higher than 115 turn off a little steam from the cream of lime pump, the valve being operated from the upper platform. The lime water tanks equalize all but the greater irregularities in the pumping rate.

TROUBLES.

In a large plant like the one at Winnipeg, troubles, which might pass unnoticed in a smaller plant, have to be reckoned with. There has never been any question as to the capacity of the plant to soften the guaranteed amount of water daily, but in order to insure smooth running we found it best to make certain changes from our original designs.

Our experience had been with intermittent plants and we designed ours at Winnipeg on that basis, making provision for many automatic features. The feed changed from one reaction tank to the other when necessary. Before sinking to sludge level, the floating discharge pipes were made to automatically raise their open ends out of water. In refilling, these pipes became submerged again only when the tanks were nearly full, thus keeping sludge out of them. Special gridiron valves, operated automatically, shut off the flow from each tank when the water sank to a certain level.

In spite of all these devices to overcome the bugbear of intermittent plants, the frequent opening and closing of valves, we decided to change our plant over to the continuous method of operation. A valve becoming coated with lime incrustation would stick occasionally or a sudden change in rate of pumping would make one tank fill before the other had properly emptied.

The changes required to make operation continuous were remarkably few in number. The chutes and draw-off pipes were added to, as already described, in order to effect more even distribution of incoming water and drawing off of the softened water. The other changes made were simply for the improvement of the plant. Cone bottoms were put in the lime water tanks to facilitate the drawing off of sludge and to make the process more uniform. Stirrers took the place of perforated pipes at the same time. The latter were designed to distribute the incoming water evenly through the layer of cream of lime, but did not do so satisfactorily.

Sponge filters we were obliged to abandon after a very thorough trial. We tried every combination of coarse and fine sponges we could devise. Sponge clippings were very inexpensive, and preliminary experiments were most satisfactory. We had four filter tanks 8 ft. in diameter and 5 ft. deep. The sponges were held between expanded metal sheets fastened on wooden grills, the upper grill being movable. The water was admitted below the sponges and passed out from spouts above to the reservoir. The filtered water for the first half-hour was clear as crystal. As soon, however, as sufficient sediment collected on the filter, it was either forced through by the compression of the sponges independent of the grills, or, if held very tightly by the grills, something broke or the path of least resistance was followed and cloudy water resulted.

We tried several combinations of sponges and cloth, using the latter as a ring under the upper grill at the sides, where leakage past the grill sometimes happened. These experiments were only moderately successful.

Sand filters could not be considered, as the great room required, on account of their high resistance was not available, and the power for cleaning would add to the expense of operation. A sand filter working on ordinary river water delivers daily about 2,500 gallons of water per square ft. of filter surface. This would have meant an installation at Winnipeg of fifteen or more 12 ft. sand filters. The resistance of the gelatinous magnesian precipitate would have made frequent washings necessary and the waste of water would have been large.

We adopted the filter press idea and made a special design. Seven presses occupying a floor space of about 315 sq. ft. did the work. The method of cleaning and filling these presses is as follows:

The wooden plates are held in the frame by the usual movable plate operated by a capstan head and screw. When a press is ready for cleaning, the end is drawn back for a few feet and the cloths with their contents are removed to the washing machine. New cloths are put in place at once and the press is ready for use. Two men, if expert, can make the change in about an hour.

The cloths are rinsed in a tank to remove most of the sludge, and then thrown into a rotary washer where the rinsing is completed. They are next given a bath of warm dilute muriatic acid, and then a final thorough wash with water.

The acid treatment is to prevent the cloths from becoming hard from crystalization of carbonate of lime among the fibers. This material will not wash out and must be removed by acid. Its occurrence does not seem to be due to lack of the usual time for completing the chemical reaction of softening, but to the peculiar composition of the Winnipeg water which makes the final few degrees of softening very sluggish indeed.

This gave us trouble in another way. Softened water filtered perfectly clear gave a deposit on the valves of the pumping engine and deposits in the condensers, as already described.

This after-reaction was very slight in amount as compared with the quantity of water passing. The plant for carbonating has already been described. It has worked very effectively, giving complete relief from all after-reaction. The degree of softening was changed but slightly, 21° instead of 22° being removed. The test for complete carbonating is the absence of color when phenolphtalein is added to the softened water.

We had much trouble in getting good lime in Winnipeg. Low grade magnesian lime was very plentiful and quite cheap, but its use was neither economical nor satisfactory. The first car loads of lime with which we were supplied contained only 45% of actual lime. This interfered with the process from start to finish, doubling the labor and clogging the apparatus. It was found cheaper to import lime from the United States at a total cost for material, freight and duty, of about $11 per ton. As the plant uses about 3 tons of lime a day, the matter of recovering lime from the sludge would be a commercial proposition, and has received serious consideration from the city authorities. The writer devised a process for removing the magnesia, the objectionable constituent of the sludge, by treatment of the wet material with carbonic acid gas (combustion gases). By this means all of the magnesia is brought into solution as carbonate while the lime is not affected. The residual carbonate of lime is then to be dried in centrifugal machines and run through a rotary kiln, to be burned into calcium oxide.

This system will be an ideal finish to the softening process at Winnipeg. More lime comes out of the water than is put in, and there will be lime to sell while the same lime originally causing the water to be hard is made the means of softening the water which comes afterward. The magnesia may be recovered by heating the solution and sold as a by-product.

ESTIMATE ON LIME RECOVERY FROM SLUDGE AT WATER SOFTENING PLANT, WINNIPEG, MAN.

1,500,000 gallon rate.

Lime used, 5,100 pounds, at $11.00 per ton	$28.05	
Coke used, 400 pounds, at 10.00 per ton	2.00	
		$30.05
Cost of treatment of sludge	$25.00	
PRODUCTS.		
(a) 1,500 pounds lime for sale	$ 4.50	
(b) 5,100 pounds lime for use	....	
(c) 900 pounds magnesia for sale	4.50	
(d) 400 pounds coke saved, because kiln will supply gas for carbonating	2.00	
		$11.00
Net cost of lime recovered for water softening	$14.00	

Daily saving due to lime recovery when running at 1,500,000 rate = $16.05 or 1.07 cts. per 1,000 gallons. When running at 2,500,000 gallon rate the saving would be $31.69, or 1.26 cts. per 1,000 gallons. The increased saving would be due to lower fixed charges per unit of output.

COST OF SOFTENING AT WINNIPEG.

Cost of softening one thousand Imperial gallons when running pumps at 1,510,000 gallon rate, the daily average when plant was installed (capacity of plant, 3,600,000 gallons).

Lime, 3.41 lbs., at $11.00 per ton	1.87	cts.	
Coke, 0.29 lbs., at 10.00 per ton	.145	"	
Acid, 0.034 lbs., at 5½c. per lb	.187	"	
Total for chemicals	2.202	cts.	2.202 cts.
Filter cloth renewals	0.155	"	
Interest at 6% on investment	0.186	"	
Depreciation on tanks, etc., at 10%	0.150	"	
Power, pumping to softening plant	0.500	"	
Power for engine running stirrers and washer, steam for lime pump and for heating of building	0.200	"	
Labor	0.977	"	
Total, excluding chemicals	2,168	cts.	2.168 cts.
			4.370 cts.

DEDUCTING POSSIBLE SAVINGS.

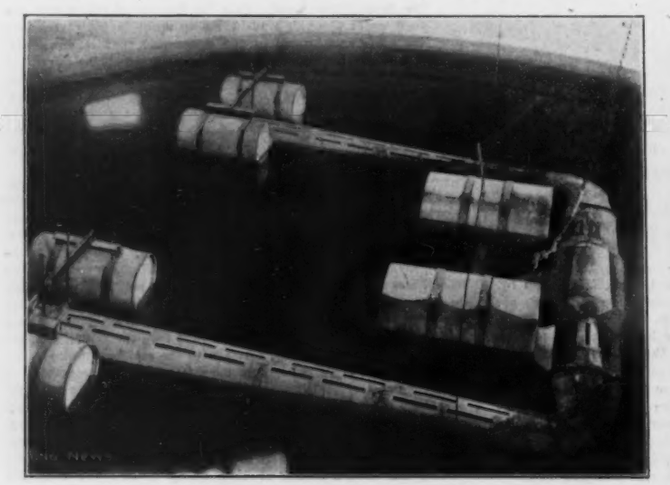
(a) Cheaper lime and acid, and saving all coke	1.16
(b) Saving in labor and fixed charges when running at 2,500,000 gal. rate	0.36
Total saving	1.52
Net cost when operating at higher rate and with possible savings in effect	2.85 cts

A rate of 2.85 cts. per 1,000 Imperial gallons means 2.36 cts. per 1,000 U. S. gallons. The present cost of 4.37 cts. per 1,000 Imperial gallons means 3.64 cts. per 1,000 U. S. gallons. This can be reduced as indicated.

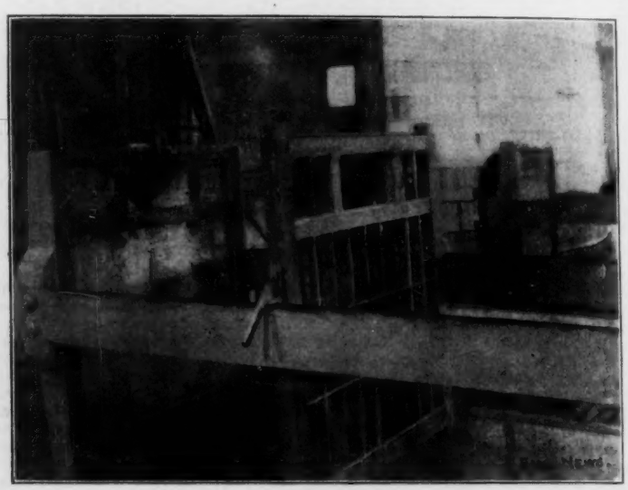
CONCLUSION.

The Winnipeg Softening Plant, the first municipal plant in North America, and one of the two largest ones in the world, has been built for less than the estimate made by Mr. Rudolph Hering, and is being operated for the figure he calculated upon with the necessary addition of the extra cost of good lime. He estimated on the use of the lime of the region about Winnipeg, not being aware of its very low grade.

The plant has been in operation since July, 1901, the trial year having ended in October, 1902. The water is very satisfactory to all consumers for both domestic and manufacturing uses.



FLOATING DRAW-OFF PIPE ON CLARIFYING TANK.



FRAME OF FILTER PRESS.